PROGRESS REPORT FOR 1933

ON ENGINEERING EXPERIMENTS CONDUCTED AT THE

PACIFIC NORTHWEST SOIL EROSION AND MOISTURE CONSERVATION

EXPERIMENT STATION

by

P. C. McGrew, Agricultural Engineer

UNITED STATES DEPARTMENT OF AGRICULTURE

Bureau of Agricultural Engineering

S. H. McCrory, Chief

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The work of the station is conducted by the Bureau of Chemistry and Soils and the Bureau of Agricultural Engineering of the United States Department of Agriculture in cooperation with the State College of Washington.

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P. C. McGrew, Agricultural Engineer
Pullman, Washington May 12, 1934

Prepared under the direction of C. E. Ramser, Senior Drainage Engineer, and Lewis A. Jones, Chief, Division of Drainage and Erosion Control
Bureau of Agricultural Engineering

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INTRODUCTION[1]

The Soil Erosion Experiment Station was started in September 1930. The first few months were spent preparing a map of the station, collecting available information on rainfall and weather records, studying the erosion problem, and making plans for the experiments. The building of terraces and installations for measuring runoff and soil losses were practically completed the fall of 1931. Six additional installations have been made since that time and two of the original installations have been discontinued.

The station is located in the Palouse Region about two miles northwest from Pullman, Washington, in Latitude 46° 45' N., Longitude 117° 12' W. The elevation of the station varies between 2471 and 2656 feet above sea level.

The steeply rolling wheat country known as the Palouse Region has now been in cultivation about fifty years. In the areas where the rainfall is eighteen inches or more, and especially in the 20 to 21 inch rainfall belt, the yield has been, and in most cases still is, excellent. The average yield of wheat over the last four years, as determined by the published wheat allotment, varied between 30 and 40 bushels per acre for nearly all the farms over a considerable area. This is actually equivalent to only half this amount per acre per year as most of the land is only cropped to wheat every second year and is either fallowed or planted to peas the other year. This yield is probably as high as has ever been produced, but this is possible

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1. The work of the station is conducted jointly by the Bureau of Chemistry and Soils and the Bureau of Agricultural Engineering, U. S. Department of Agriculture, and practically all experiments involve work of both bureaus. Although this report is on the engineering phases of the work, it includes results from some of the work of the Bureau of Chemistry and Soils in order to make the report on each experiment as complete as possible.
Acknowledgments are made to W. A. Rockie, Superintendent (on leave), C. L. Dwerdorff, Acting Superintendent, and A. J. Johnson, Farm Foreman, for suggestions in carrying on the engineering experiments.

only because of better varieties of wheat and better tillage methods. Nearly all fields now have low producing areas, where the subsoil has been exposed by erosion and, as the soil at these places will not readily absorb the rainfall, there has been an increase in runoff and erosion. The contour map of Fig. 1 shows the 202 acre station and on this area are four hills, all under cultivation, where the land slope is 50 per cent on the steepest part. This farm is typical of the region as there are many 50 per cent slopes under cultivation; in fact, only a few have been found which are not in cultivation. In Figures 2, 3, and 4 are shown typical eroded fields, illustrating the types of erosion occurring in the region. These pictures also illustrate the types of topography.

WEATHER RECORDS

Recording gages at the Station are used to obtain records of the rainfall, temperature, humidity and barometric pressure. Daily readings are made of maximum and minimum temperatures. Records of wind velocity and sunshine are recorded at the State College of Washington about four miles from the Station and these records can be obtained at any time. In work on erosion control the rainfall and temperature records appear to be of most importance. The rainfall record is used directly to compare the runoff to the rainfall. The temperature has an important influence on the runoff and the record is very useful for reference in working up runoff data. During a considerable part of the erosion season, especially when the snow is melting, there will be runoff during the day which will continue all night if the temperature does not go below freezing. When the temperature goes below freezing, the

Fig 1 PACIFIC NORTHWEST SOIL EROSION EXPERIMENT STATION, PULLMAN, WASH. 1931

(a)

(b)

Fig. 2 (a) One season's erosion left a soil deposit 12 to 15 inches deep nearly burying a disk left in a field near Colton, Washington

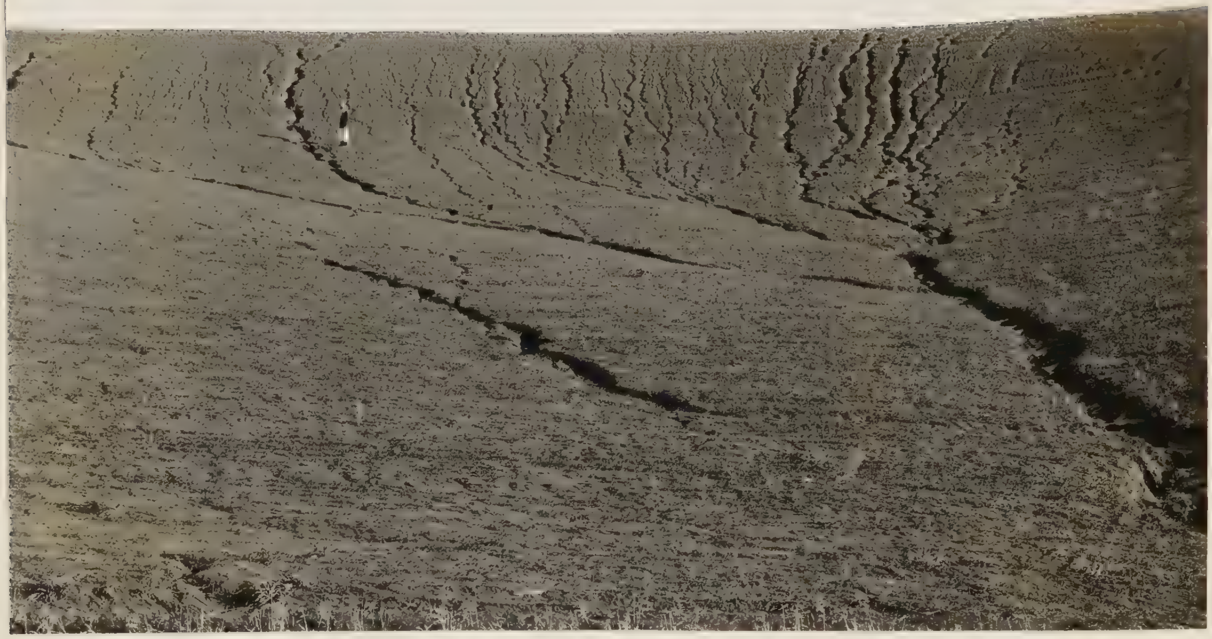
(b) Same soil deposit as (a) looking toward hills from which the soil was eroded. Crop was winter wheat planted on fallow.

(a)

(b)

Fig. 3 (a) Erosion on a typical field near Diamond, Washington. Every acre of this land is under cultivation and was in a crop of winter wheat at the time this erosion occurred.

(b) Eroded field near Waits burg, Washington. These gullies were seeded across in the fall.



(a)

(b)

Fig. 4 (a) Erosion in field near Palouse, Washington
(b) Gully erosion near Dayton, Washington.
(Photographs by A. L. Hafenrichter, Soil Erosion Service)

water usually freezes in the flume first causing a backing up of the water which will show on the chart as an increased head. If the temperature chart shows a freezing temperature about the time there is an increased head, it is clear that the increased head is due to freezing, but if the temperature goes up or a light rain falls with the temperature above freezing, the increase in head is known to be an actual increase in runoff. This is frequently checked by actual field inspection, but this is not always practical as the conditions described occur day after day and usually at night.

On the steep slopes of the Palouse region it is difficult to locate rain gages where they will not be effected by the topography. In order to check this factor, gages were established at several locations on the farm. The locations of recording gages 2 and 5 and standard gage No. 1 are shown on the map of Figure 1. Gage No. 5 is believed to be in the best location. Also gages were located on a 30 per cent south slope west of the plot setup. Other gages have since been established on the hilltop insider Terrace 20 and on the 48 per cent north slope at the second plot setup. Gage No. 4 on the south slope is a standard gage and Gage No. 6 setting a few feet to one side is of a standard type set vertically but with a special top cut to a 30 per cent angle corresponding to the slope. The records of these gages are as follows:

1933	Recording Gage No.5	Recording Gage No.2	Standard Gage No.1	Standard Gage No.4 on 30% S. slope	Gage No.6 with top cut to 30% on 30% S. slope	Gage No.3 on hill inside Ter. 20	Official record at State College of Washington
Jan.	4.56	4.43	4.61	4.26	4.57	4.30	4.49
Feb.	2.80	2.76	2.85	2.70	2.82	2.66	3.15
Mar.	1.89	1.84	1.92	1.80	1.96	1.73	1.84
Apr.	.60	.56	.72	.61	.60	.47	.70
May	.91	.85	1.09	.97	.89	.79	.85
June	1.07	1.01	1.19	1.08	1.08	.91	.89
July	.25	.22	.30	.26	.20	.19	.30
Aug.	.47	.48	.51	.43	.45	.50	.60
Sept	1.65	1.55	1.90	1.73	1.60	1.26	1.55
Oct.	4.41	4.40	4.54	4.37	4.36	4.08	3.46
Nov.	1.73	1.66	1.73	1.71	1.75	1.67	1.67
Dec.	8.43	8.23	9.24	7.76	9.13	7.46	7.12
Total	28.77	27.99	30.60	27.68	29.41	26.02	26.62

The records for 1931 are of no especial interest for comparing locations of gages as all gages were moved October 25, 1931. The original locations were established soon after the station was established and before any experimental work was planned. Gages Nos. 1 and 5 were only a few feet apart before being moved and both checked closely to No. 2. The 1931 rainfall at the Erosion Farm was about $1\frac{3}{4}$ inches less than the official station at the College, while in 1932 and 1933 the rainfall at the Erosion Farm was about 2 inches more. There appears to be considerable local variation and longer time records are needed before drawing conclusions. The College rain gage is on top of a three story building and they are planning to check the records with a second gage to be installed at another location.

Recording gages Nos. 5 and 2 check rather closely for most rains. No. 2 recording .24 inches higher in 1932 and No. 5 recording .78 inches higher in 1933. Standard Gage No. 1 recorded about 1.0 inch higher than the others in 1932 and 2.2 inches higher in 1933. The rainfall appears to be

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consistently higher for Gage No. 1. Standard Gage No. 4 on a 30% slope recorded below gages 1, 2, and 5 almost every month while special gage No. 6 with the top cut to a 30 per cent angle corresponding to the slope, recorded fairly close to the standard gages in the better locations. Standard Gage No. 3 on the hilltop inside terrace 20 registered consistently lower than gages Nos. 2 and 5.

The snowfall is measured at several locations by use of snow boards about 1 x 3 feet. The depths are first measured with a rule to determine the average depth and after determining the average depth, a column of snow is cut out by inverting a standard rain gage, pushing it down to the board and sliding a piece of tin over the opening so that the gage can be lifted without the snow falling out. The snow is melted and measured in a standard brass tube. The snowfall is recorded the same for all gages and for this reason the monthly totals are rather close for some winter months when there is considerable snowfall. Records have been kept of the snow in the gages with the funnel tops removed but these vary as much as 100 to 500 per cent in some cases and are nearly always considerably less than the actual snowfall. .

<u>Rains of High Intensity:</u> The rates of rainfall in general are low as shown in Table 10. However, rains of high intensity do occur sometimes in local areas although no such rains have occurred at the College since the recording gage was installed 21 years ago. One such rain occurred on July 30, 1931, as reported in the 1931 Annual Report and in more detail in State College of Washington Bulletin No. 271--"Erosive Effects of Heavy Summer Rains in Southeastern Washington," by W. A. Rockie and L. C. McGrew.

considerably higher than Gage No. 1. [illegible] Gage No. 4 on a [illegible] [illegible] below gages 1, 5, and 3 almost every month while [illegible] gage No. 6 [illegible] [illegible] per cent [illegible] to the slope, recorded fairly close to the standard gages [illegible] [illegible] Gage No. 7 on the [illegible] [illegible] lower than gages Nos. 2 and 5.

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The rain of high intensity covered an area of about 50 square miles approximately 11 miles west and 3 miles north of the Erosion Station.

A similar rain occurred the afternoon of September 9, 1933, over an area of 15 to 20 square miles centering three to four miles east of the Erosion Station. The rainfall at the Station was .21 inches while a rain of two to three inches in 1½ hours fell three miles distant. The rain was accompanied by hail to a depth of about one inch over part of the area. The morning after the rain a trip was made through the area and records obtained of the amount of rainfall. These measurements were made by the writer wherever containers were found which were known to have been empty the previous day. The containers were measured accurately and readings corrected in case the bottom is smaller than the top. The results are as follows:

Rain on Afternoon, September 9, 1933.

Chris Stairwald farm--3.1 inch in 29¼ x 56¾ inch vat. Rain lasted a little over an hour--one inch of hail, some still being on ground at 10 A.M. Sept. 10.
Nelson farm--2.7 inches (average of two measurements about 300 feet apart.)
Price Tate farm--2.5 inches--average of two buckets.
Carl King farm--1.8 inches in bucket--not much hail.
Pritchard farm--1.0 inch--rain much less and not much runoff.
D. H. Vanderpool farm--.75 inch--no runoff.

The area of heavy rain was partly in the 26.1 square mile watershed of Gaging Station 7. The channel had been dry for some weeks and the runoff came down the channel in almost a wall of water. The water at the head appeared to be about a foot deep and back a few feet was two to three feet deep. Runoff samples were taken as follows:

	When Taken		Discharge in	soil content in
Date of Rain	Date	Time of day	cu. ft/sec.	% by weight
Sept. 9, 1933	Sept. 9	5:25 P.M.	Head water	9.05
" " "	" "	5:30 P.M.	255	7196
" " "	" "	5:40 P.M.	308	6.74
" " "	" "	6:35 P.M.	360	3.54
" " "	" "	7:15 P.M.	920(max)	-
" " "	" "	8:10 P.M.	480	2.25
" " "	" "	9:05 P.M.	135	1.99
" " "	Sept.10	8:55 A.M.	4	.59
" " "	" 11	1:45 P.M.	.5	.16

There was runoff from only about one-third of the drainage area and yet the maximum discharge at the gage was almost as large as for any runoff recorded. The soil content in runoff water was the highest ever recorded and the soil losses averaged .57 tons per acre for the entire watershed and were many times this amount on some of the fields.

On the same afternoon three other rains of a similar nature occurred at other points in Eastern Washington--one between Palouse and Colfax, one near Garfield, and one near Tekoa. Two of the areas were inspected and the erosion appeared somewhat less than for the area near the Erosion Station.

In the area of most intense rain, runoff occurred from all sloping land regardless of cover although there was no noticeable soil losses from standing wheat stubble, grass, or alfalfa. The heavy soil losses were from fallow land, land which had been in peas and any land not covered by vegetation.

Although these summer rains are spectacular in their results, they are infrequent and are a minor problem as compared to the sheet washing

which occurs day after day nearly every winter over the most productive wheat land of Eastern Washington and adjoining portions of Idaho and Oregon.

Weather Conditions As Affecting Erosion and Runoff: The erosion during the past three years varied considerably due to variations in rainfall, snow, and temperatures. The daily rainfall records for 1933 are given in Table No. 1 and Fig. 5. The rainfall for 1931 was below normal and for 1932 and 1933 was above normal, the monthly totals and U. S. Weather Bureau normal being as follows:

Month	Normal U. S. Weather Bureau[1]	Gage No. 5 on Erosion Station		
		1931	1932	1933
January	2.70	2.22	3.26	4.56
February	2.09	1.42	2.92	2.80
March	2.07	3.91	4.50	1.89
April	1.50	1.09	1.28	.60
May	1.57	.50	1.96	.91
June	1.26	1.30	.26	1.07
July	.52	.05	.77	.25
August	.63	0	.15	.47
September	1.23	.78	.13	1.65
October	1.51	1.84	2.29	4.41
November	2.97	2.35	4.44	1.73
December	2.68	3.06	2.42	8.43
Total	20.73	18.52	24.38	28.77

1. U. S. Weather Bureau records kept at State College since 1893.

The general weather conditions during the different years were as follows:

October to December 1931--Precipitation was about normal but distribution and intensities were such that only a small amount of runoff occurred.

January to March 1932--Precipitation was 3.8 inches above normal. Rapid melting of snow, and rains caused serious erosion on several days during this period.

October to December 1932--The precipitation was 2.0 inches above

TABLE I. RAINFALL AT EROSION STATION FOR 1933

GAGE No. 5 Near Center Farm

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1	.63[1]										.11		
2	1.16[1]		.30		.07		.06	.10			.91	.17	
3	.02[1]						.12	.08			.50	.14	
4	.10[1]				.05			.16					
5	.07							.08				.45	
6		.04	.01									1.82	
7	.55		.25[1]		.04	.13							
8	.26			.06[1]		.60			.04			.20	
9	.08		.34[1]			.27	.07		.21			1.53	
10				.02								.31	
11		.70[1]		.11								.16	
12			.03									.17	
13												.13	
14	.10								.11			.10	
15					.25							.35[1]	
16		.58[1]	.07		.03					.04	.04	.15[1]	
17				.12	.02							.15[1]	
18		.28[1]	.05		.40				.14	.09		.65	
19										1.37	.10	.13	
20		.03	.02					.05				.25	
21	.14[1]		.10[1]									.18	
22		.22	.04						.45	.51		.79	
23		.66[1]							.58				
24	.06[1]	.03[1]											
25			.04		.04								
26	.37[1]	.22[1]							.05			.46[1]	
27										.20	.07		
28		.12	.21			.07			.07	1.21		.07	
29	.04[1]		.13	.22									
30	.26[1]		.30	.07						.36		.07	
31	.72[1]									.73			
Total	4.56	2.80	1.89	.60	.91	1.07	.25	.47	1.65	4.41	1.73	8.43	28.77

1. Snow

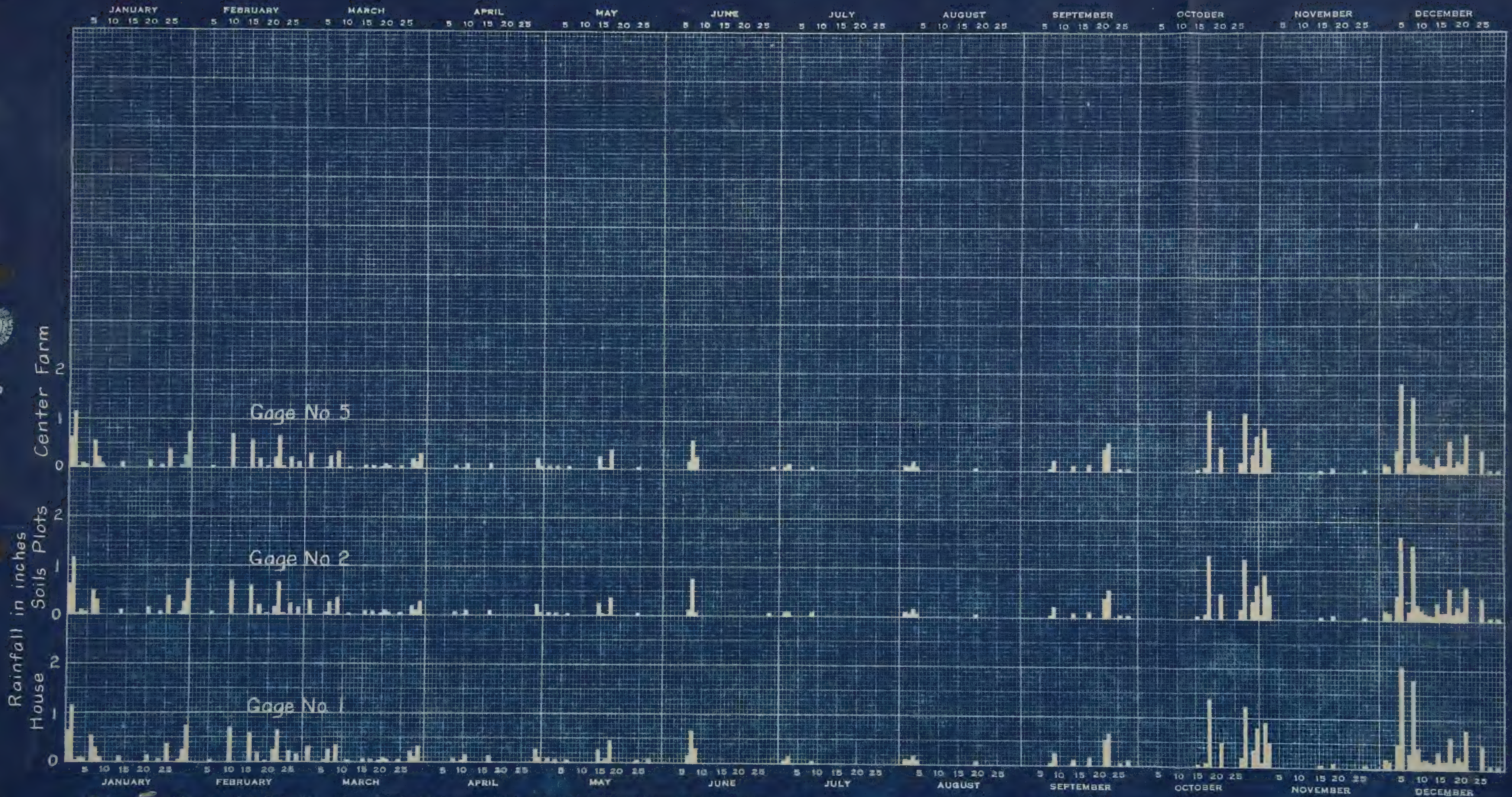

Fig. 5 Record of daily percipitation on the Pacific Northwest Soil Erosion Experiment Farm for the year, 1933

normal, most of the excess being during November. The runoff during November was from rain on unfrozen ground, while the December runoff was caused by melting snow with the ground frozen.

January to March 1933--The precipitation was 2.4 inches above normal and was characterized by heavy snow and freezing temperatures during the latter part of January and most of February. Runoff and erosion were heavy in early January and again in late February and early March.

October to December 1933--The precipitation was 7.4 inches above normal, 5.7 inches of the excess coming in December. There was only a small amount of snow and the ground was not frozen except for a light crust on a few occasions. Not much runoff occurred in October and November but the runoff and soil losses were heavy in December. The runoff was due to rain on unfrozen ground in excess of the absorptive capacity of the soil.

The yearly distribution of rainfall at Pullman shows a normal of below 1.6 inches each month from April to October inclusive, with only .52 inches for July. The months from November to March each have a normal exceeding 2.0 inches, with a maximum of 2.97 for November. Thus the normal for the 7 months of April to October is 8.22 inches and for the other five months is 12.57 inches. With this distribution of rainfall and practically all the rains of low intensity, the erosion problem becomes essentially a winter erosion problem, usually starting in November and ending in March. The rainfall during the winter season, although low in intensity, saturates the soil and runoff with serious erosion results. For example, in December 1933, there was rain every day but one for the

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eighteen days from December 5 to 22, the total being 7.53 inches and on the last day of this period, a rain of .79 inches fell with the highest intensity so far recorded for the Station. This rain caused serious soil losses as shown in Tables 10 to 14.

The rainfall increases slightly to the east of Pullman and decreases to the west to less than eight inches near the Columbia River. The erosion is less where the rainfall is less, although it may not be a direct proportion. At the Adams Branch Substation of the State College of Washington the average annual rainfall since 1916 has been slightly below eight inches. During the last four years, with rainfall below normal, there has been one year with no runoff, but serious runoff and erosion occurred the other three years. However, the water erosion in this area of low rainfall is less serious than the wind erosion.

MAXIMUM RATES OF RAINFALL AND RUNOFF

The rates of rainfall and runoff for 1933 are given for each terrace and water shed in Tables 10 to 14. The rates of runoff are not always in proportion to the rainfall or size of watershed but in some cases depend on the distribution of snow. Some of the outstanding days for the years of 1932 and 1933 are grouped for convenience in comparing the different terraces and watersheds as follows:

Station	Drainage area (acres)	Maximum Rates of Runoff (inches per hour) Jan. 11 1932	Mar. 27-28 1932	Dec. 26 1932	Jan. 5 1933	Dec. 6 1933	Dec. 22 1933
Ter. 2	.56	-	.094	.021	.050	.066	.393
Ter. 3A	1.04	-	-	.054	.067	.267	.410
Ter. 3	1.22	.023[1]	.277[1]	.041	.015	.309	.471
Ter.4	1.85	.008	.320[2]	.051	.007	.166	.241
Ter. 5	1.26	.014	.273	.039	0	.126	.181
Ter. 6	4.68	.008	.205	.052	.021	.104	.114
Ter. 7	2.09	.038	.072	.105	.138	0	.076
Ter. 13	1.52	-	-	.021	.039	.124	.124
Ter. 15	.89	-	-	.054	.089	.602	.813
Ter. 16	.82	.080	.219	.021	.037	.472	.605
Ter. 17	.92	Trace	.276	.017	.009	.517	.625
Ter. 18	1.18	Trace	.200	.030	.003	.261	.261
G.S. 2	68.2	.247	.166	.040	.175	.077	.118
G.S. 4	2.33	.170	.302	.085	.136	.421	.472
G.S. 5	14.4	-	-	.046	.103	.003	.027
G.S. 6	15.2	-	-	.030	.052	.389	.269
G.S. 7	16704.	-	-	-	.009	.024	.039

1. 35 foot vertical spacing
2. Break in Terrace 3 let water on Terrace 4.

Date	Maximum Rates of Rainfall (inches per hr.) 5 Min.	10 Min.	15 Min.	20 Min.	30 Min.	Total Rain-fall (inches)	Maximum Total Runoff (inches)	Remarks
Jan. 11, 1932	.33	.33	.33	.31	.30	.69	.79(G.S.2)	Rain on snow
Mar. 27-28 1932	.42	.36	.32	.30	.24	.73	.75(G.S.4)	Rain on snow
Dec. 26, 1932	.16	.16	.16	.15	.15	.27	1.31(Ter.7)	Rain on snow
Jan. 5, 1933						.07	1.64(G.S.2)	Runoff from melting snow
Dec. 6, 1933	.48[1]	.36	.32	.21	.18	1.82	1.23(G.S.4)	No snow
Dec. 22, 1933	.72	.42	.28	.21	.14	.79	.74(G.S.4)	No snow

1. The maximum rate of rainfall was about 1.2 inches per hour for a one minute period.

The total rainfall and maximum runoff are recorded in adjacent columns. In all but two cases the daily runoff for the station having maximum runoff exceeded the rainfall. This was caused by melting snow. On January 5, 1933, the runoff for Gaging Station 2 was 1.64 inches and the rain for that day was only .07 inches. On this day the maximum rate

of runoff for Gaging Station 2 was .175 inches per hour.

On March 27-28, 1932, the maximum 5 minute rainfall rate was .42 inches per hour, which fell on ground partly covered by snow. The highest rate of runoff was for Gaging Station 4 with .302 inches per hour (not including Terrace 4 which received water from break in Terrace 3).

The maximum rate of runoff on December 6, 1933, was .602 inches per hour for Terrace 15 which exceeds the 5 minute rainfall rate of .48 inches per hour. From an examination of the rainfall chart it appears that the rainfall rate was about 1.2 inches per hour for a one minute period which may account for the high runoff rate.

The runoff and rainfall rates on December 22, 1933, exceeded any previous records. The maximum rate of rainfall for a 5 minute period was .72 inches per hour. The maximum rate of runoff for Terrace 15 was .813 inches per hour which exceeded the maximum rate of rainfall for a 5 minute period. This high rate mayhave been caused by a higher rate of rainfall over the watersheds of Terraces 15, 16, and 17. A high wind caused some vibration of the pen on the rain gage and the rate of rainfall for less than 5 minutes cannot be read.

TERRACING STUDIES

The terraces on the Station are on a South slope varying from 12 to 32 per cent, with some terraces extending around the hill on the west slope as shown in the map of Fig. 1. A description of terraces giving grade, length, spacing, height, and width is given in Table 2.

The cropping system of wheat--Summer fallow is most widely used in the Palouse Region and was adopted for the terraced land. The erosion

with this cropping system is believed to be more serious than any other farming practice, but excellent yields and weed control have made this system of farming profitable. This system cannot continue indefinitely although it can be prolonged if the erosion can be materially reduced. The cropping system of the farm is shown in Table 3, for the fields as shown in Fig. 1. This does not include the small experimental plots.

The drifting of snow introduces a problem in connection with terracing which requires study. The snow drifts sometimes form across the terrace channel and if a sudden runoff occurs, the water may break over the terrace. This condition occurred a few times during the winters of 1931-32 and 1932-33, but did not occur during 1933-34. A few more years records are needed to determine whether this factor is important. The distribution of snow varies widely and is discussed under the terracing experiment of different land slopes. The rates of runoff are low as compared to other sections of the country and the channel capacities of terraces do not need to be large.

The Parshall flume, with water stage recorder, and the Ramser silt sampler are used on all installations for measuring runoff and soil losses from terraced land. These records, along with observations of erosion, cost records, and machinery studies are used as a basis for determining the value of terracing in erosion control

EROSION AND RUNOFF FROM GRADED TERRACES
WITH DIFFERENT VERTICAL SPACINGS (Sub-Project No. S.E. 7.1)

The terraces included in this study are 780 feet long and are on land slopes of 20 to 28 per cent. The vertical spacings on the original

TABLE NO. 2. DIMENSIONS AND DRAINAGE AREAS OF TERRACES ON PACIFIC NORTHWEST SOIL EROSION EXPERIMENT STATION

Terrace No.	Fields	Drainage Area	Average Land slope Between Terraces	Avg. Vertical interval Between Terraces	Fall Along Terrace	Length	Dimensions of Terraces: Average Width[2]	Dimensions of Terraces: Average Height	Remarks
		Acres	per cent	feet	in./100'	feet	feet	feet	
1	7	1.82	15.6[1]	16.2[1]	12	475	28	.9	
2	7	.56	22.6	15.0	12	400	28	.9	
2A	7	.33	23.5[1]	8.6[1]	level	395	28	1.3	open end
3A	7	1.04	27.6	15.0	12	780	24	1.1	
3	7	1.22	27.8	20.0	12	780	24	.9	
4	7	1.85	23.6	25.0	12	780	25	1.2	
5	7	1.26	20.0	15.0	12	780	25	1.3	
6	7	4.68	16.2	14.7	12	2274	24	1.2	
7	7	2.09	14.5	15.0	12	780	23	1.2	
8	7	.09	17.2[1]	9.0[1]	level	111	26	1.0	open end
9	7	.14	23.7	10.0	level	175	24	.7	closed ends
10	7	.22	23.7	15.0	level	200	27	.9	closed ends
10A	7	.21	15.0[1]	7.0[1]	level	192	27	.9	open end
11	7	.73	22.6	20.0	level	400	26	1.1	closed ends
11A	7	.41	18.0[1]	11.0[1]	level	284	26	1.1	open end
12	7	.69	20.6	10.0	level	690	27	1.3	closed ends
13	7	1.52	15.2	13.8	level	780	27	1.2	open end
14	7	.57	14.7[1]	11.3[1]	level	625	23	.9	circle terrace
15	7	.89	24.0	17.0	24	685	27	1.2	
16	7	.82	26.7	13.5	18	775	26	1.2	
17	7	.92	23.5	14.2	12	780	25	1.0	
18	7	1.18	18.4	14.0	6	780	25	1.1	
19	7	.56	10.0[1]	7.6[1]	level	630	25	1.0	circle terrace
20	5	.81	10.3[1]	8.3[1]	level	870	25	1.0	circle terrace

1. Upper terrace. Land slope and vertical interval are average to center of ridge above.
2. Width measured from upper edge of cut to lower edge of fill.

TABLE 3. CROP ROTATION PLAN

Soil Erosion Farm, Pullman, Washington

Field No.	Acres[1]	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940
1	10	peas	peas	s.wheat	fallow	peas	peas	peas	peas	peas	peas
2	18	fallow	s.wheat	fallow	w.wheat	fallow	s.wheat	fallow	s.wheat	fallow	s.wheat
3	21	fallow	peas	s.wheat	fallow 15 pot.	w.wheat	peas	w.wheat	fallow	w.wheat	peas
4	30	s.wheat	fallow	w.wheat	s.clover	s.clover	w.wheat	s.wheat	fallow	w.wheat	fallow
5	26	fallow	w.wheat	s.wheat	fallow & grass	w.wheat	fallow	w.wheat 20 pot.	fallow	w.wheat 15 pot.	fallow
6	29	peas & fallow	w.wheat	s.wheat 16 pot.	w.wheat	peas	w.wheat	peas	w.wheat	peas	w.wheat
7	49	peas	w.wheat	fallow	w.wheat	fallow	w.wheat	fallow	w.wheat	fallow	w.wheat
8	16	peas	pot.	w.wheat	s.wheat	s.wheat	pot.	s.wheat	peas	s.wheat	pot.
W. Wheat			103	39	73	61					
S. Wheat		24	28	63	18	16					
Peas		99	28	0	0	25					
Potatoes			16	19	16	15					
All crops		123	175	121	107	117					
Fallow		76	24	69	61	48					
Plots,Grass,etc.		3	3	12	34	37					
All land		202	202	202	202	202					

1. The cropped area is frequently less due to experimental plots being taken out.

experiment were 15, 25, and 35 feet. The erosion for the 35 foot vertical spacing was so severe that the terrace channel was almost completely filled with soil the first winter, causing overtopping several times and it was decided to construct an intermediate terrace. The measurements of soil and water losses both before and since the construction of the intermediate terrace are summarized in Table 4. A detailed record of runoff and soil loss for 1933 is given in Table 10. In comparing the results for this experiment, as shown in Table 4, it is noted that Terrace 5 with a 15 foot vertical spacing lost 1.82 tons per acre and Terrace 3A with the same spacing lost 5.11 tons. Terrace 4 with a 25 foot vertical spacing and 3 with a 20 foot spacing had soil losses of 3.03 tons per acre and 4.56 tons respectively. The water losses were in the same order as the soil losses. From an examination of the location of these terraces, as shown on the map of Fig. 1, it will be noted that the upper terrace of this group had the greatest soil loss and that each terrace below lost less soil than the one above. The fact that the soil and water losses seem to have no relation to the vertical spacing indicates that other factors have a greater influence on this particular group of terraces than the vertical spacing. These factors are believed to be the soil and land slope. According to the soil survey, the soil is progressively better and more absorptive from the upper to the lower terrace in this experiment. The crop yield of winter wheat for 1932 was taken across this group of terraces at the locations shown on the map of Figure 1. The average for the undisturbed

experiment were 17, 21, and 31 feet. The erosion for the 31 foot vertical spacing was so severe that the terrace channel was almost completely filled with soil the first winter, causing overtopping several times and it was decided to construct an intermediate terrace. The measurements of soil and water losses both before and since the construction of the intermediate terrace are summarized in Table 4. A detailed record of runoff and soil loss for 1932 is given in Table 14. In comparing the results for this experiment, as shown in Table 4, it is noted that Terrace 9 with a 19 foot vertical spacing lost 1.86 tons per acre and Terrace 11 with the same spacing lost 3.11 tons. Terrace 8 with a 15 foot vertical spacing and 9 with a 20 foot spacing had soil losses of [illegible] tons per acre and [illegible] tons respectively. The water losses vary in the same order as the soil losses. From an examination of the location of these terraces as shown on the map of Fig. 1, it will be noted that the upper terrace of this group had the greatest soil loss and that each terrace below lost less soil than the one above. The fact that the soil and water losses seem to have no relation to the vertical spacing indicates that other factors have a greater influence on this particular group of terraces than the vertical spacing. These factors are believed to be the soil and land slope. According to the soil survey, the soil is progressively better and more absorptive from the upper to the lower terrace in this experiment. The crop yield of winter wheat for 1932 was taken across this group of terraces at the locations shown on the map of Figure 1. The averages for the individual terraces

TABLE 4. EROSION AND RUN-OFF FROM GRADED TERRACES
WITH DIFFERENT VERTICAL SPACINGS

Period	Total Rain-fall	Total Run-off Ter. 4	Ter. 3	Ter. 3A	Ter. 5	Soil Loss per Acre Ter. 4	Ter. 3	Ter. 3A	Ter. 5	Remarks
	inches	inches	inches	inches	inches	tons	tons	tons	tons	
Sept. to Dec. 1931	8.03	0	0	-	0	0	0	-	0	Winter wheat following peas
Jan. to Apr. 1932	11.96	.95	1.16[1]	-	1.04	3.92	4.38	-	2.39	Winter wheat following peas
May to Oct. 1932	5.56	0	0	0	0	0	0	0	0	Winter wheat
Nov. to Dec. 1932	6.86	.86	.76[2]	.58	.60	.02	.02[2]	.05	.02	Winter wheat stubble
Total 1932	24.38	1.81	1.92	-	1.64	3.94	4.40	-	2.41	
Jan. to Mar. 1933	9.25	1.15	.47	1.71	.61	.07	.03	.51	.03	Winter wheat stubble
Apr. to Oct. 1933	9.36	0	0	0	0	0	0	0	0	Fallow
Nov. to Dec. 1933	10.16	1.86	2.99	4.23	1.24	2.05	4.53	4.60	1.20	Winter wheat
Total 1933	25.77	3.01	3.46	5.94	1.85	2.12	4.56	5.11	1.23	
Avg. 1932-1933	26.58	2.41	3.46[3]	5.94[3]	1.74	3.03	4.56[3]	5.11[3]	1.82	

Terrace No.	Drainage Area	Land Slope	Vertical Spacing	Length	Grade
	Acres	%	feet	feet	in./100'
4	1.85	23.6	25.0	780	12
3	1.22	27.8	20.0	780	12
3A	1.04	27.6	15.0	780	12
5	1.26	20.0	15.0	780	12

1. 35 foot vertical spacing
2. 20 foot vertical spacing
3. Data for 1933 only

portion between terraces is as follows:

Terrace No.	Yield of Wheat	Avg. Land slope	Soil Loss per Acre 1932	1933	Average	Vertical Spacing
	bu./acre	%	tons	tons	tons	feet
3A	27.3	27.6	-	5.11	5.11[2]	15
3	30.3	27.8	4.40[1]	4.56	4.56[2]	20
4	34.8	23.6	3.94	2.12	3.03	25
5	38.6	20.0	2.41	1.23	1.82	15

1. 35 foot vertical spacing
2. Data for 1933 only

It is seen that the crop yield is inversely in proportion to the soil losses and that the yield increases progressively from the upper to the lower terraces of this experiment. The upper slope is slightly steeper than the lower slope, as shown in the table above, which would also tend to increase the soil losses for the upper terraces. A more detailed soil survey is now being made and crop yields for 1934 will be taken at definite intervals along each terrace, both on the terrace and between terraces.

In Table 4 it is noted that the ground was covered by winter wheat stubble the fall of 1932 and spring of 1933, and that the soil loss under this condition was small as compared to the loss from winter wheat following peas the winter of 1931-32 and winter wheat following summer fallow the fall of 1933. The results are summarized in the following table.

Type of Ground cover	Tons soil lost per acre per year				Total Runoff in Inches per year			
	Ter.3A	Ter.3	Ter.4	Ter.5	3A	3	4	5
Ground cover, winter wheat stubble	.28[1]	.02	.04	.02	1.14	.62	1.00	.60
winter wheat following peas('31)& fallow(33)	4.60[2]	4.46[3]	2.98	1.80	4.23[2]	2.08[3]	1.40	1.14

1. Losses large due to terrace being bare following construction in stubble field after harvest 1932.
2. Data for 1933 only as terrace was not constructed until fall of 1932.
3. 35 foot vertical spacing spring of 1932.

The soil loss was from 16 to over 200 times greater for wheat planted in the fall on summer fallow or land which had been in peas as compared to land covered by wheat stubble.

EROSION AND RUNOFF FROM GRADED TERRACES WITH DIFFERENT LENGTHS (Sub-Project No. S.E. 7.2)

Terraces 2, 5, and 6 having lengths of 400, 780, and 2274 feet respectively are included. The vertical spacing is approximately 15 feet and the grade is 12 inches per 100 feet for all terraces. The record of runoff and soil losses is summarized in Table 5. The detailed record for 1933 is given in Table 11. The average annual soil loss was 1.87 tons per acre for a terrace 400 feet long, 1.82 tons for a terrace 780 feet long, and 3,94 tons for a terrace 2274 feet long. The soil loss was more than twice as great for the terrace 2274 feet long as compared to the shorter terraces. There was more washing in the channel of the longer terrace due to a larger quantity of water. The longer terrace was on about the same soil as the terrace 780 feet long. Subsoil was exposed on parts of the watershed of Terrace 2, 400 feet long, which would tend to increase the soil losses as compared to the other two terraces. The poor soil and slightly steeper land slope for the terrace 400 feet long probably accounted for the soil losses being almost the same as for the 780 foot terrace. Soil was better and the land slope less for the terraco 2274 feet long, but these factors were overbalanced by the length of the terrace and it appears quite conclusive that the soil losses are greater for the longer terrace.

The runoff was in the same order as the soil losses, although the

The soil loss was from 16 to over 200 times greater for wheat planted in the fall on [illegible] land [illegible] by [illegible].

[illegible]

Terraces 2, 5, and 6 having lengths of 400, 780, and 2274 feet respectively are included. The vertical spacing is approximately 15 feet and the grade is [illegible] per 100 feet [illegible]. The record of runoff and soil losses is [illegible]. The [illegible] that is given in Table [illegible]. The [illegible] soil loss [illegible] acre for a terrace 400 feet long, 1.82 tons for a terrace 780 feet long, and 2.94 tons for a terrace 2274 feet long. The soil loss was more than twice as great for the terrace 2274 feet long as compared to the shorter terraces. There was more washing in the channel of the longer terrace due to a larger quantity of water. The longer terrace was on about the same soil as the terrace 780 feet long. Subsoil was exposed on parts of the watershed of terrace 2, 400 feet long, which would tend to increase the soil losses as [illegible] to the other two terraces. The poor soil and slightly steeper land [illegible] [illegible] loss for the terrace 2274 feet long, but these factors were overbalanced by the length of the terrace and it appears quite conclusive that the soil [illegible] longer terrace.

The runoff was in the same order as the soil losses, although the

TABLE 5. EROSION AND RUN-OFF FROM GRADED TERRACES OF DIFFERENT LENGTHS

Period		Total Rain-fall	Total Run-off Ter. 2	Ter. 5	Ter. 6	Soil Loss per Acre Ter. 2	Ter. 5	Ter. 6	Remarks
		Inches	Inches	Inches	Inches	tons	tons	tons	
Sept. to Dec.	1931	8.03	0	0	0	0	0	0	Winter wheat following peas
Jan. to Apr.	1932	11.96	.98	1.04	1.35	1.69	2.39	5.64	Winter wheat following peas
May to Oct.	1932	5.56	0	0	0	0	0	0	Winter wheat
Nov. to Dec.	1932	6.86	.26	.60	1.46	.01	.02	.12	Winter wheat stubble
Total	1932	24.38	1.24	1.64	2.81	1.70	2.41	5.76	
Jan. to Mar.	1933	9.25	.84	.61	1.77	.04	.03	.06	Winter wheat stubble
Apr. to Oct.	1933	9.36	0	0	0	0	0	0	Fallow
Nov. to Dec.	1933	10.16	2.40	1.24	1.90	2.00	1.20	2.06	Winter wheat
Total	1933	28.77	3.24	1.85	3.67	2.04	1.23	2.12	
Avg. 1932-1933		26.58	2.29	1.74	3.24	1.87	1.82	3.94	

Terrace No.	Drainage Area	Land Slope	Vertical Spacing	Length	Grade
	Acres	%	Feet	Feet	in./100'
2	.56	22.6	15.0	400	12
5	1.26	20.0	15.0	780	12
6	4.68	16.2	14.7	2274	12

difference between the 400 foot and 780 foot terraces was greater. The 400 foot terrace, having subsoil exposed in places, had 2.29 inches runoff compared to 1.74 inches for the 780 foot terrace on good soil. The runoff of 3.24 inches for the 274 foot terrace was more than for the other terraces due to more snow accumulating on the watershed of this terrace.

EROSION AND RUNOFF FROM GRADED TERRACES
WITH DIFFERENT LAND SLOPES (Sub-Project No. S.E. 7.3)

Terraces 7, 5, 17 and 3A are included in this experiment and are on land slopes of 14.5, 20.0, 23.5, and 27.6 per cent respectively. All terraces are 780 feet long and have a uniform fall of 12 inches per 100 feet. Terrace 3A was not installed until the fall of 1932 and only 1 1/2 years records are available for this terrace. The measurements of soil and water losses are summarized in Table 6. A detailed record of results for 1933 is given in Table 12. The soil losses in general increase as the slope increases, the average annual loss being at the rate of .57 tons per acre for a 14.5 per cent slope, 1.82 tons for a 20.0 per cent slope, 7.20 tons for a 23.5 per cent slope, and 5.11 tons for a 27.6 per cent slope. There are other factors besides the degree of slope, which influence the amount of runoff and soil losses, the soil probably being the most important. Terrace 7 on a slope of 14.5 per cent is near the foot of the slope and is on excellent soil, fairly well drained. Terrace 5 on a 20.0 per cent slope is on good soil but not quite so productive as Terrace 7. Terrace 3A and 17 are on upper slopes where the subsoil is exposed in places and the soil is much less productive. The results of the various experiments show that the soil loss from a deep productive soil is less than where the soil is thin. This statement is true only within certain

TABLE 6. EROSION AND RUN-OFF FROM GRADED TERRACES ON DIFFERENT LAND SLOPES

Period	Total Rain-fall	Total Run-off Ter. 7	Ter. 5	Ter. 17	Ter. 3A	Soil Loss Per Acre Ter. 7	Ter. 5	Ter. 17	Ter. 3A	Remarks
	inches	inches	inches	inches	inches	tons	tons	tons	tons	
Sept. to Dec. 1931	8.03	0	0	0	0	0	0	0	0	Winter wheat following peas
Jan. to Apr. 1932	11.96	2.06	1.04	1.09	not installed	.74	2.39	5.32	not installed	Winter wheat following peas
May to Oct. 1932	5.56	0	0	0	0	0	0	0	0	Winter wheat
Nov. to Dec. 1932	6.86	2.17	.60	.39	.58	.06	.02	.02	.05	Winter wheat stubble
Total 1932	24.38	4.23	1.64	1.48	-	.80	2.41	5.34	-	
Jan. to Mar. 1933	9.25	4.25	.61	.15	1.71	.06	.03	.02	.51	Winter wheat stubble
Apr. to Oct. 1933	9.36	0	0	0	0	0	0	0	0	Fallow
Nov. to Dec. 1933	10.16	.72	1.24	3.78	4.23	.28	1.20	9.03	4.60	Winter wheat
Total 1933	28.77	4.97	1.85	3.93	5.94	.33	1.23	9.05	5.11	
Avg. 1932-1933	26.58	4.60	1.74	2.70	5.94[1]	.57	1.82	7.20	5.11[1]	

Terrace No.	Drainage Area	Land Slope	Vertical Spacing	Length	Grade
	Acres	%	feet	feet	in./100'
7	2.09	14.5	15.0	780	12
5	1.26	20.0	15.0	780	12
17	.92	23.5	14.2	780	12
3A	1.04	27.6	15.0	780	12

1. Data for 1933 only

limits, however, as the soil loss seems to decrease when the subsoil is exposed, as compared to when the soil is thin, although the per cent runoff may increase. The subsoil is exposed over a larger part of the watershed of Terrace 3A than for Terrace 17 which may account for the smaller soil loss from Terrace 3A even though the slope was slightly steeper. The runoff was greater from Terrace 3A than for 17 which also would point to the same conclusion. Detailed soil surveys are now being made and more complete crop yields for 1934 should be helpful in interpreting the results for this experiment.

The soil loss from Terrace 7 was only .57 tons per acre and yet the average runoff was 4.60 inches which was exceeded only by Terrace 3A. From an examination of Tables 6 and 12 it will be noted that the major part of the runoff did not occur on the same days or even the same month in some cases. Terrace 7 is on a lower slope and the snow lay much deeper over the watershed than for the other terraces. The major part of the runoff from Terrace 7 was from melting snow, while for the other terraces probably less than half the runoff was from melting snow. For example, the runoff for the winter of November 1932 to March 1933 amounted to 6.42 inches for Terrace 7 and varied from .54 to 2.29 inches for the other terraces in this experiment, the major part of the runoff for terrace 7 being from melting snow. From November to December 1933 most of the runoff was from rain and Terrace 7 lost only .72 inches while Terrace 3A lost 4.23 inches. It should be noted that the above runoff figures are in inches and not in per cent runoff. Even though there was considerable runoff from melting snow for Terrace 7,

[illegible]

soil loss from Terrace 3A even though the slope was slightly steeper. The runoff was greater from Terrace 3A than for 17 which also would point to the same conclusion. Detailed soil surveys are now being made and more complete crop yields for 1934 should be helpful in interpreting the results for this experiment.

The soil loss from Terrace 7 was only .57 tons per acre and yet the average runoff was 4.60 inches which was exceeded only by Terrace 3A. From an examination of Tables 6 and 12 it will be noted that the major part of the runoff did not occur on the same days or even the same month in some cases. Terrace 7 is on a lower slope and the snow lay much deeper over the watershed than for the other terraces. The major part of the runoff from Terrace 7 was from melting snow, while for the other terraces probably less than half the runoff was from melting snow. For example, the runoff for the winter of November 1932 to March 1933 amounted to 6.42 inches for Terrace 7 and varied from .54 to 2.29 inches for the other terraces in this experiment, the major part of the runoff for terrace 7 being from melting snow. From November to December 1933 most of the runoff was from rain and Terrace 7 lost only .72 inches while Terrace 3A lost 4.22 inches. It should be noted that the above runoff figures are in inches and not in per cent runoff.

[illegible]

the per cent runoff probably was not large. The amount of snow on the watershed of this terrace was so much greater than for some ofthe other terraces that it would not be surprising if the moisture absorbed over the watershed of Terrace 7 was greater than the annual rainfall. Plans were made for measuring some of the variations in snow depth during the winter of 1933-34 but the snowfall was the smallest recorded for many years and no results were obtained. It is planned to continue these studies.

EROSION AND RUNOFF FROM TERRACES WITH DIFFERENT GRADES (Sub-Project No. S.E. 7.4)

The terraces included in this experiment at its inception were Terraces 16, 17, and 18, having grades of 18, 12, and 6 inches fall per 100 feet. After the first year flumes and silt sampling installations were made for Terrace 13 which is a level terrace, and Terrace 15 having a fall of 24 inches per 100 feet. The latter two terraces are not quite comparable to the others in all respects, such as land slope in the case of Terrace 13, and length and vertical spacing in the case of Terrace 15. These factors, however, are believed to be of lesser importance as compared to the grades of the terraces.

The location of these terraces is shown on the map of Fig. 1, and the summarized results for 1932 and 1933 are given in Table 7. The detailed results for 1933 are given in Table 13. The soil loss was 1.28 tons per acre for the level terrace, 2.90 tons for a grade of 6 inches per 100 feet, 7.20 tons for a 12 inch grade, 10.36 tons for an 18 inch grade, and and 13.67 tons for a 24 inch grade. There was noticeable washing in the channel of Terrace 15 with a fall of 24 inches per 100 feet and some

[illegible]

terraces that it would not be surprising if the positive [illegible] over the watershed of Terrace [illegible] made for measuring some of the variations in [illegible] during the winter of 1933-34 but the snowfall was the smallest recorded for many years and no results were obtained. It is planned to continue these studies.

[illegible]

The terraces included in this experiment at the inception were Terraces 16, 17, and 15, having grades of 18, 12, and 6 inches fall per 100 feet. After the first year flumes and [illegible] and [illegible] of 24 inches per 100 feet. The latter two terraces are not quite comparable to the others in all respects, such as land slope in the case of Terrace 12, and length and vertical spacing in the case of Terrace 15. [illegible]

The location of these t[illegible] is shown on the [illegible] of Fig. 1, and [illegible] results for 1932 and 1933 are given in [illegible]. The detailed results for 1933 are given in [illegible] 1.28 tons [illegible], 2.90 tons for a grade of 6 [illegible] feet, 7.20 tons for a 12 inch grade, 10.36 tons for an 18 inch grade, and 13.67 tons for a 24 inch grade. There was noticeable washing in the channel of Terrace 15 with a fall of 24 inches per 100 feet and some

washing in Terrace 16 with a fall of 18 inches per 100 feet. Terrace 17 with a 12 inch fall did not show a tendency to cut although most of the soil washing into the terrace channel was carried to the outlet. There was noticeable depositing of soil in the channel of Terrace 18 with a 6 inch grade, although the grade was sufficient to prevent the formation of bars across the channel. Soil was deposited in level Terrace 13 and bars formed across the channel causing ponding of water to some extent. Views of the terraces in this experiment are shown in Fig. 2, for the conditions at the end of the erosion season 1931-32 and again for 1933-34. The actual soil losses were greater for 1933-34 although the reverse would appear to be true from looking at the pictures. The erosion for 1931-32 tended toward small finger gullies which show in a picture while the 1933-34 was sheet erosion which in some cases was barely noticeable by observation although the measurements proved the losses were large.

The terraces with 6 and 12 inch grades gave best results from the standpoints of operation and soil losses. Level Terrace 13 lost less soil but bars formed in the channel causing ponding and killing the crop and endangering the terrace embankment. Very little of the crop was killed in Terraces 18 and 17 with 6 and 12 inch grades respectively. The soil loss was more than twice as much for the 12 inch grade as compared to the 6 inch grade, although this difference was probably exaggerated due to slight difference in soil and land slope. It is believed, however, that the grades in general should be from 12 inches down rather than more than 12 inches. In general the fall along the terrace should be more on the steeper slopes as there is more tendency for bars to block the channel, the terrace

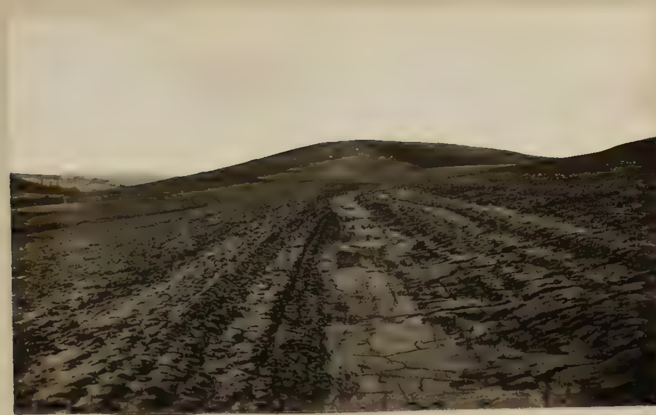
TABLE 7. EROSION AND RUN-OFF FROM GRADED TERRACES
WITH DIFFERENT GRADES

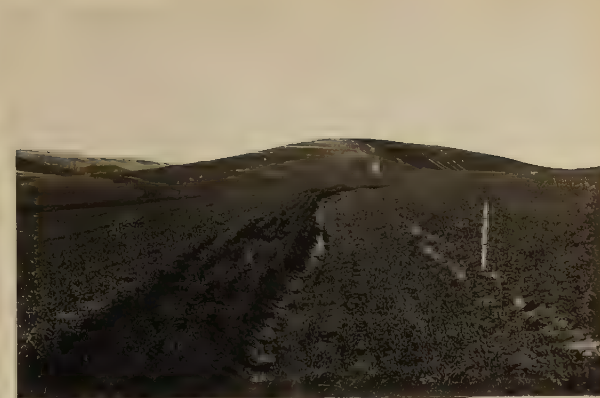
Period	Total Rain-	Total Run-off					Soil Loss Per Acre					Remarks
		Ter. 13	Ter. 18	Ter. 17	Ter. 16	Ter. 15	Ter. 13	Ter. 18	Ter. 17	Ter. 16	Ter. 15	
	inches	inches	inches	inches	inches	inches	tons	tons	tons	tons	tons	
Sept. to Dec. 1931	8.03	0	0	0	0	0	0	0	0	0	0	Winter wheat following peas
Jan. to Apr. 1932	11.96	-[1]	.71	1.09	2.15	-[1]	-[1]	2.13	5.32	9.27	-[1]	Winter wheat following peas
May to Oct. 1932	5.56	0	0	0	0	0	0	0	0	0	0	Winter wheat
Nov. to Dec. 1932	6.86	.34	.47	.39	.46	.86	.01	.02	.02	.05	.08	Winter wheat stubble
Total 1932	24.38	-	1.18	1.48	2.61	-	-	2.15	5.34	9.32	-	
Jan. to Mar. 1933	9.25	.93	.07	.15	1.17	2.52	.07	0	.02	.18	.20	Winter wheat stubble
Apr. to Sept. 1933	4.95	0	0	0	0	0	0	0	0	0	0	Fallow
Oct. to Dec. 1933	14.57	3.45[2]	3.27	3.78	4.90	5.91	1.21[2]	3.65	9.03	11.22	13.47	Winter wheat
Total 1933	28.77	4.36[2]	3.34	3.93	6.67	8.43	1.28[2]	3.65	9.05	11.40	13.67	
Avg. 1932-1933	26.58	4.36[3]	2.26	2.70	4.64	8.43[3]	1.28[3]	2.90	7.20	10.36	13.67[3]	

Terrace No.	Drainage Area	Land Slope	Vertical Spacing	Length	Grade
	Acres	%	feet	feet	in/100'
13	1.52	15.2	13.8	780	0 (level)
18	1.18	18.4	14.0	780	6
17	.92	23.5	14.2	780	12
16	.82	26.7	13.5	780	18
15	.85	24.0	17.0	685	24

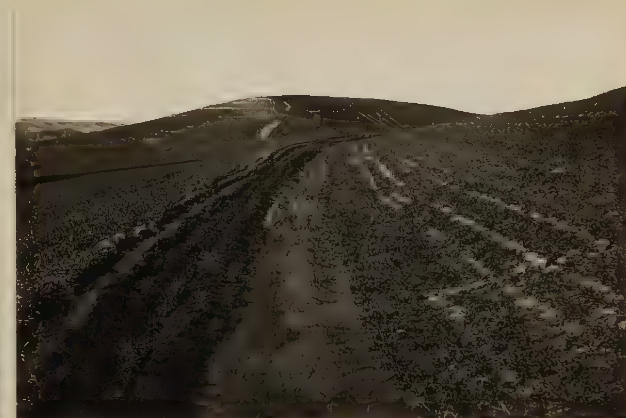
1. Not yet installed
2. Terrace 12 would not hold all of run-off and water ran over dyke at end into Terrace 13. The combined areas of 12 and 13 were used in working up data for such periods.
3. Data for 1933 only.

34

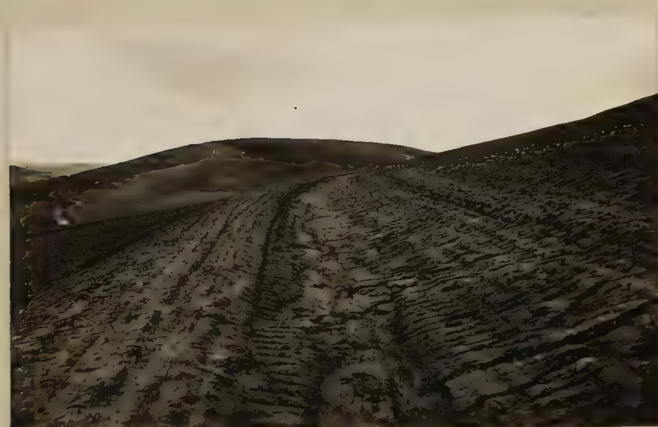




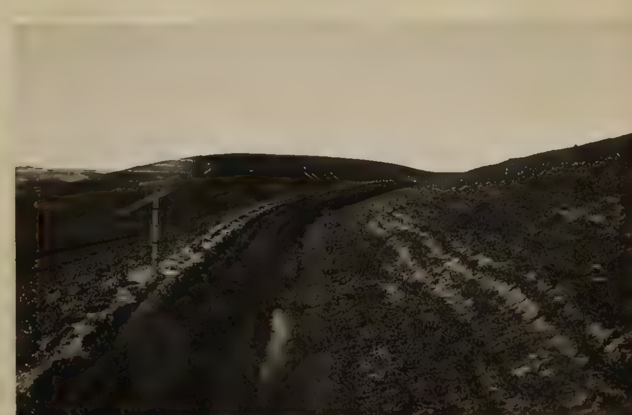
1931-32 Ter. 13 Level 1933-34



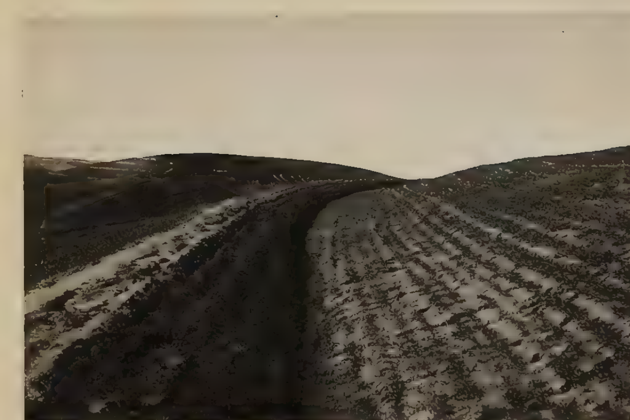
1931-32 Ter.18 6"fall/100' 1933-34



1931-32 Ter.17 12"fall/100' 1933-34



1931-32 Ter.16 18"fall/100' 1933-34



Ter. 15 24" fall/100' 1933-34

Fig. 6 Views of terrace channels at end of erosion seasons showing the difference in amount of erosion for grades of level 6, 12, 18, and 24 inches fall per 100 feet.

channel will usually have less capacity, and it is more difficult to obtain the desired grade in constructing the terrace. Also if a wide vertical spacing is used, the grade of the terrace should be steep enough so bars formed by washing between terraces will not block the channel.

LEVEL TERRACES WITH CLOSED ENDS
(Sub-Project No. S.E. 7.5)

Closed end level Terraces 9, 10, 11, and 12, having vertical spacings of 10, 15, 20, and 10 feet respectively are included in this experiment. The average land slope is about 23 per cent and the lengths of terraces 175 to 690 feet. During 1932 and spring of 1933, records were taken of the depth of water in the terrace channels. The capacities of Terraces 9, 10, and 11 were exceeded several times and water flowed over the dyke at the end as shown in the Annual Report for 1932. Terrace 12 held all of the runoff the winter of 1932-33.

The terraces were maintained the fall of 1933 and plans were made to continue the measurements of the depth of water. However, the runoff during December greatly exceeded the capacity of all these terraces and the dykes at the end were lowered so the excess water would waste and not overtop the terrace. Water stood in the channels of Terraces 8, 9, and 10, and 2A from December until after the middle of April, a period of four and one-half months, even though the rainfall was below normal for February and practically no runoff occurred during March and April.

The results indicate that it is not practical to hold all of the runoff in a level terrace. The rates of rainfall and runoff are low, however, as compared to other sections of the country and it is believed that tile drainage of level terraces would take care of the excess water. It is hoped

that an experiment can be started soon to test out this possibility.

CONSTRUCTION AND MAINTENANCE OF
TERRACES (Sub-Project No. S. E. 7.6)

A detailed account of the cost of terraces was given in the 1932 Annual Report and the types of terraces for different land slopes were discussed and illustrated. Representative terraces on slopes of from 14.5 to 20.0 per cent had an average cost of $22.98 per mile of terrace and $2.21 per acre. Under similar conditions the cost on slopes of from 20.6 to 27.8 per cent averaged $34.07 per mile of terrace and $4.63 per acre. The cost per unit length of terrace was 50 per cent more for the steeper land while the cost per acre was twice as much for the steeper land as compared to the more gentle slopes.

In operating tillage machinery on terraced slopes such as found on the Erosion Station it has not been possible to throw the soil toward the center from both sides. The soil is thrown toward the center of the terrace on the upper side and on the lower side the tandem disk is used to kill weeds and prepare a seed bed. The terrace is lowered a considerable amount during a summer fallow season. A record of the maintenance and heights of terraces is given in Table 8. In 1933 the heights of terraces were measured just after maintaining in the spring. The field was fallowed during the summer and the heights were measured again after the summer tillage operations of disking twice, harrowing and weeding with rod weeder. Terraces on land slopes of 20.0 per cent and less were lowered an average of 1.7 inches and terraces on land slopes more than 20.0 per cent were lowered an average of 2.9 inches.

TABLE NO. 8. RECORD OF TERRACE CONSTRUCTION AND MAINTENANCE

Ter. No.	Land Slope	Construction Period: April and Sept. 1931	Construction Period: Average Height Oct.[2] 1931	Maintain Terraces Nov. 1932	Maintain Terraces May 19, 1933	Height Terraces: May 23 1933	Height Terraces: July 20-28 1933	Height Terraces: Sept. 18 1933	Maintain Terraces Sept. 1933	Maintain Terraces April 5 1934	Remarks
	%	trips	inches	trips	trips	inches	inches	inches	trips	inches	
1	15.6[3]	35	9.8	4	2	9.0	7.9		2	11.3	
2	23.0	34	9.7	2	2	13.4	11.3		2	13.2	
3	27.8	31	6.1	7	2	11.6	9.2		2	11.6	
3A	27.6	41(Nov. 1932)	12.0	0	2	10.8	8.4		2	13.5	
4	23.6	29	8.9	4	2	12.8	11.5		2	14.6	
5	20.0	22	9.9	3	1	13.5	11.5		2	15.1	
6	16.2	21	11.5	2	2	14.7		13.4	2	13.8	
7	14.5	23	11.8	2	2	17.1	14.4		2	14.7	
8	17.2[3]	30	11.8	9	5	10.1		10.0	2	12.3	
9	23.7	30	9.0	6	3	12.0		8.0	2	8.6	
10	23.7	31	9.0	5	2	10.8		8.8	2	10.2	
11	22.6	37	10.1	4	2	14.1		10.3	2	13.1	
12	20.6	24	11.3	6	1	14.9		10.7	2	15.3	
13	15.2	24	11.6	6	1	13.8		11.4	2	14.2	
14	14.7[3]	29	13.4	4	0	11.7		-	0	11.2	Planted to alfalfa 1932
15	24.0	36	12.6	4	4	13.3		8.1	2	14.4	
16	26.7	44	16.0	4	2	11.5		8.4	2	14.3	
17	23.5	30	13.3	3	2	10.3		6.8	2	12.2	
18	18.4	30	15.5	3	2	12.3		10.0	2	13.2	
19	10.0[3]	32	15.9	3	0	11.7		-	0	12.5	Planted to sweet clover 1933
20	10.3[3]	46	10.0	4	0	11.9	(maintain June)	13.2	0	12.1	

1. The 8 foot Corsicana and Caterpillar Twenty tractor were used for constructing and maintaining terraces.
2. Measurements just after completion.
3. Upper Terrace. Land slope is average to center of ridge above.

The terraces were maintained in the fall by making two trips on the upper side with the Corsicana, after which the field was seeded to winter wheat. The heights were measured after the winter's erosion and averaged 3.1 inches higher than when measured the previous fall just before being maintained. The terraces are now compact and are not lowered as rapidly as during the first year. It appears that terraces should be maintained by making one or two trips along the upper side each season the land is tilled, which would be every two years using the summer fallow system, and annually if cropped annually.

STUDIES OF FARM OPERATIONS AND THE USE
OF MACHINERY ON TERRACED LAND
(Sub-Project No. S.E.7.7)

Many of the implements used in the Palouse Region are especially designed for use on steep land and operate quite satisfactorily. In some places, however, ditches are becoming rather numerous and considerable difficulty is experienced. It has long been the practice to operate along the contour and work around the hills so far as possible and when a ditch becomes so deep it cannot be crossed, it interferes seriously with the working of the field. The smaller ditches, which are far more common, cause excessive breakage to machinery.

The various farm implements were discussed in the 1932 Annual Report and in more detail in the report of February 23, 1933. The implements in general operate successfully on the steep slopes but will not operate successfully across the terraces. The drilling of wheat with a nine-foot drill is shown in Fig 7 . Some of the disks over the channel do not touch

Fig. 7 (above) Drilling wheat on lower side of Terrace 16. (below) Drilling ridge and channel of Terrace 16. The nine foot drill is too wide to do a good job under such conditions. The furrow openers over the channel do not touch the ground.

Fig. 8 Heavy tandem disk operating on terrace

the ground. This illustrates the difficulty using a wide rigid implement. This can be overcome by using narrower implements so that one wheel can be in the channel when the other is on the ridge or where the slope is not too steep the terrace can be built to take care of wider implements. Best results are obtained on terraced land by operating parallel to the terraces and reducing the number of times a terrace is crossed to a minimum. In order to do this successfully, an implement must be used which can operate back and forth on a steep slope. The mold board plow will not turn the furrow up the slope on the steep land and thus is not adapted to terraced land. A heavy tandem disk, 22 inch disks with 9 inch spacing, was used in place of the plow in working the terraced land, as shown in Fig. 8 . The disk does not cover or kill weeds as well as a mold board plow but by following with a second disking a good job can be done. For summer fallow work the operations can be made a few weeks apart and the net cost will not exceed that where the plow is used. The disk type of implement mixes the stubble with the soil rather than covering in a single layer about 6 inches deep and the erosion is noticeably less where the disk is used. Some feel that the crop yield will be much less where the disk is used. There was no apparent difference according to the measurements we have made as reported under Sub-Project No. S.E. 7.13. However, additional records are needed before this can be determined conclusively.

SOIL MOVEMENT DOWN THE SLOPES
(Sub-Project No. S.E. 7.8)

Profile lines AA to HH, as shown on the map in Figure 1, were established to study the rate of soil movement down the slope. Permanent

concrete bench marks were set at the upper and lower ends of each line and during the fall of 1932 levels were run over each line taking ground elevations every six inches along the slope. These measurements will be repeated the fall of 1934 and at later two year intervals. The two year interval is used because a two year rotation is being followed on most of the lines and it is desired to have the surface conditions the same each time the measurements are taken.

Lines AA, BB, and FF are on terraced land with different slopes and CC, DD, EE, GG, and HH are on unterraced land with different slopes. The cropping system is winter wheat and summer fallow (winter wheat 1932, 1934, etc.) for lines AA, BB, EE, FF, and GG. Line DD was wheat in 1932 and the following year was planted to grass. Line HH is in a rotation of wheat and fallow with trees planted on the ridge at the upper end of the line.

The original measurements have been plotted and the two year results will be taken the fall of 1934 and plotted for comparison with the original measurements.

RUNOFF AND SOIL LOSSES FROM WATERSHEDS OF DIFFERENT CHARACTERISTICS INCLUDING TERRACED AND UNTERRACED LAND (Sub-Project No. S.E. 7.9)

In this experiment the runoff and soil losses are measured for unterraced areas of different sizes and with different vegetative cover for comparison with each other and with terraced areas.

The runoff at Gaging Stations 2, 4, 5, and 6 is measured with Parshall flumes and water stage recorders. At Gaging Station 7 a water stage recorder records the depth of flow in the stream channel and the runoff is determined from a rating curve drawn from data obtained by current meter measurements.

A Ramser silt sampler is installed at Gaging Station 4 and for the other stations hand samples are taken frequently during periods of runoff. The hand sampling system is not entirely satisfactory and the results are no doubt subject to large errors on some days, although these are believed to be compensating over the erosion season. A runoff sampling device, described elsewhere in this report, has been developed for use on these larger installations.

The drainage area and description of the various watersheds is as follows:

Gaging Station 4. This small watershed of 2.33 acres is on a south slope averaging about 14.5 per cent and is adjacent to a terraced area as shown on the map of Figure 1. The cropping conditions for the past three years were as follows:

1931- Peas during summer--planted to winter wheat in fall
1932- Winter wheat--stubble standing after harvest
1933- Stubble standing in spring--fallowed during summer--
planted to winter wheat in fall.

Gaging Station 5. This watershed of 14.4 acres is in a field adjacent to the Station and on similar slopes and soil conditions. The cropping system of wheat-fallow has been practiced on this field and this installation was established to measure the losses from a small watershed with this common cropping system. Gaging Station 6 has the same cropping system but on alternate years. The cropping system of Gaging Station 5 the past three years was as follows:

1931- Winter wheat--stubble left standing after harvest
1932- Stubble standing in spring--followed during summer--
planted to winter wheat in fall.
1933- Winter wheat--stubble left standing after harvest.

Gaging Station 6. This watershed of 15.2 acres is in a field adjacent to the station and is near Gaging Station 5. The cropping system of wheat-fallow is the same as Gaging Station 5 except it is on alternate years. The crops the past three years were as follows:

1931- Stubble standing in spring--fallowed during summer--planted winter wheat in fall.
1932- Winter wheat--stubble left standing after harvest
1933- Stubble standing in spring--fallowed during summer--planted to winter wheat in fall.

Gaging Station 2. This is a typical watershed having a drainage area of 68.2 acres, the location being shown on the map of Figure 1. This watershed includes the plot setup and parts of 5 different fields so the surface cover is never uniform over the area. The principal cropping conditions the past three years were as follows:

1931- 57.8 acres fallow planted to winter wheat in fall--10.4 acres wheat with stubble standing after harvest.
1932- 39 acres wheat with stubble left standing after harvest--19 acres peas--10.2 acres fallow planted to winter wheat in fall.
1933- 43 acres wheat with stubble left standing after harvest--25.2 acres fallow planted to winter wheat in fall

Gaging Station 7. The area of this watershed is 16,704 acres (26.1 square miles). This area is representative of the wheat growing area of the Palouse Region and includes a large enough area so that each year is a fair average so far as cropping conditions are concerned. The major portion is divided between winter wheat, peas, and summer fallow with some spring wheat. A small part of the watershed consists of alfalfa, pasture, brush, timber, and roads.

The detailed records of runoff and soil losses for 1933 are given

[illegible]

[illegible]
to winter wheat in fall.

[illegible] Station 2. This is a typical watershed having a drainage area [illegible]

[illegible]
[illegible] standing after harvest--[illegible]
[illegible] to winter wheat in fall.
[illegible]

[illegible] Station 7. The area of this watershed is 17,704 acres [illegible]

in Table 14 and the summary of records since the installations were made are given in Table 9. The foot notes to Table 9 give the surface cover or crop occupying the fields for Gaging Stations 4, 5, and 6 while these conditions for Gaging Station 2 are given in the description of this station. In every case the soil loss is large during the season following the planting of winter wheat on fallow land or following peas and conversely the soil loss is small when the standing wheat stubble is in the field. The soil loss for Gaging Station 2 was 25.61 tons per acre during 1932 when most of the area was planted to winter wheat following fallow, and in 1933 the soil loss was 7.73 tons when an average of only 34 acres was in fallow. This wide variation was partly due to the different crop conditions and partly due to seasonal variation. Gaging Stations 4, 5, and 6 are each farmed as units so the crop is uniform over each watershed. In each case the soil loss was small while wheat stubble was standing, the loss being less than one ton per acre, and was large during the season following the planting of winter wheat.

For the year 1933 the soil loss for the watershed of 16,704 acres was 8.24 tons per acre and for the 2.33 acre watershed was 11.90 tons per acre with the two watersheds of 14.4 and 15.2 acres being between. The 68.2 acre watershed lost 7.73 tons per acre, the smaller loss probably being due to a vegetative cover of a greater per cent of the area. In 1932 the soil losses for the 2.33 acre and 68.2 acre watersheds were 22.53 and 25.61 tons per acre respectively. It is planned to continue these measurements in order to determine the losses over large watersheds as compared to small watersheds and plots.

TABLE NO. 9. EROSION AND RUN-OFF FROM WATERSHEDS
OF DIFFERENT SIZES AND CHARACTERISTICS

Period		Total Rain-fall	Total Run-off					Soil Loss Per Acre				
			G.S. 4	G.S. 5	G.S. 6	G.S. 2	G.S. 7	G.S. 4	G.S. 5	G.S. 6	G.S. 2	G.S. 7
		inches	inches	inches	inches	inches	inches	tons	tons	tons	tons	tons
Jan. To Apr.	1932	11.96	4.58[1]	not installed	not installed	8.52	not installed	22.50[2]			25.07	
May to Oct.	1932	5.56	0	-	-	0		0			0	
Nov. to Dec.	1932	6.86	1.46[3]	.66[1]	.37[3]	1.19	.18	.03[3]	.05[1]	0[3]	.54	0
Total	1932	24.38	6.04	-	-	9.71	-	22.53			25.61	
Jan. to Mar.	1933	9.25	5.30[3]	4.69[1]	6.60[3]	6.80	7.98	.29[3]	9.05[1]	.40[3]	4.19	3.25
Apr. to Oct.	1933	9.36	.07	.01	.30	.03	.71	.07	0	0	0	.59
Nov. to Dec.	1933	10.16	5.36[1]	1.15[3]	5.13[1]	3.71	4.37	10.90[1]	.03[3]	7.92[1]	3.54	4.40
Total	1933	28.77	10.73	5.85	12.03	10.54	13.06	11.26	9.06	8.32	7.73	8.24
Avg. 1932-1933		26.58	8.38			10.12		16.90			16.67	

G. S. No.	Drainage Area
4	2.33 acres
5	14.4 acres
6	15.2 acres
2	68.2 acres
7	18704 acres

1. Winter wheat on fallow
2. Winter wheat following peas
3. Standing wheat stubble

The soil loss from graded terraces varied rather widely, depending on the land slope, soil and special conditions as discussed under the terrace experiments. The two year average soil loss was .57 tons per acre for Terrace 7, 1.82 tons for Terrace 5, and 7.20 tons for Terrace 17. The average annual soil loss of these three terraces is 3.20 tons per acre as compared to an average of 16.67 tons and 16.90 tons per acre for Gaging Stations 2 and 4 respectively.

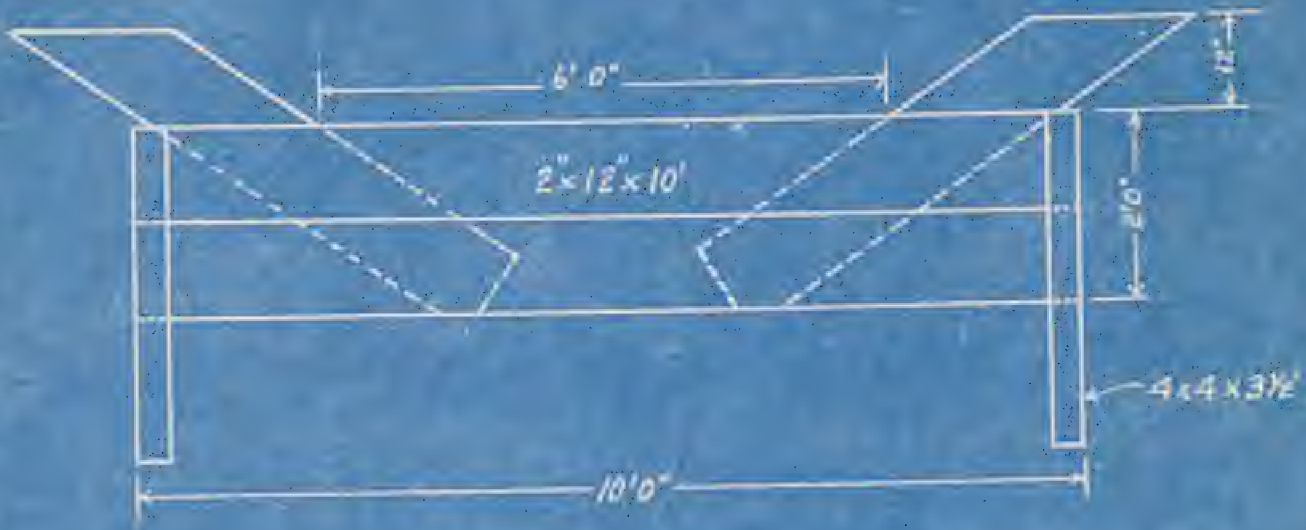
The water losses follow to some extent the soil losses, although there are frequent exceptions. When the runoff was the result of rain falling on unfrozen ground, the soil loss was greatest from the areas having the most runoff, as for example: November and December 1933 as shown in Table 9. However, when the ground is frozen and there is considerable snow, the snow is likely to be deeper on fields with standing stubble as the tendency is for the snow to blow off portions of fields having no vegetative cover. With the ground frozen the soil will not absorb the water and a large amount of runoff may result, as for example, from January to March 1933 as given in Table 9. Gaging Stations 4 and 6 with a cover of wheat stubble had 5.30 and 6.60 inches runoff respectively with soil losses of .29 and .40 tons per acre, while Gaging Station 5 with 4.69 inches runoff had a soil loss of 9.05 tons per acre. The upper few inches would sometimes thaw in places resulting in serious erosion for Gaging Station 5, while the stubble on Gaging Stations 4 and 6 held the soil so the erosion was negligible. For the larger drainage areas, there is a considerable amount of seepage included in the records of the water

losses. This is true especially of Gaging Stations 2, 6, and 7. It is difficult to separate this from the surface runoff. This seepage increases the amount of the water losses by a considerable amount but has practically no effect on the soil losses.

CHECK DAMS IN GULLIES AND TERRACE OUTLET DITCHES
(Sub-Project No. S.E. 7.10)

In the fall of 1933 check dams, or baffles, were installed in the two terrace outlet ditches on the station under a Public Works Project. Prior to the installation of these check dams, there was considerable cutting in some places, especially the longer ditch draining terraces 1 to 7. The baffles were made from 2 x 12 rough plank spiked together with a 4 x 4 post at each end. A drawing of the baffle is shown in Fig. 9. These baffles were installed with a drop of 2 to 2.2 feet between baffles, the slight variation being made to fit them in between terraces. The horizontal spacing v ried from about 8 to 20 feet depending on the land slope. The crest of the baffle was set slightly below the desired level for soil in the ditch and the ditch graded to a smooth, almost flat bottom with sloping banks and with 3 to 6 inches of soil covering the baffles so that it can be readily crossed with farm machinery. The ditch was planted to brome grass with a small mixture of ladak alfalfa. Views of the ditches after the grass was seeded are shown in Fig. 10. This ditch will be a good location for testing the effectiveness of a sod forming grass in gully, control, and at points where any washing may start the baffles will prevent the extension of the wash.

In the heavier soil the clay subsoil offers great resistance to rapid erosion and gullies are only a minor problem. Some of the most productive



Material

3 pieces 2"x12"x10' (cut one on diagonal for wings)
2 " 4"x4"x3½'
1 lb. 20d nails
Total 69⅓ bd. ft. lumber

Fig. 9 Baffle used in Terrace Outlet Ditches

(a)

(b)

Fig. 10 (a) View of outlet ditch for Terraces 1 to 7, and (b) outlet ditch 15 to 18, after construction of baffles and seeding to grass.

land, however, is in the Walla Walla region and the foothills of the Blue Mountains, and here the soil is lighter and gullies form easily. In Figs. 3 and 4 are shown views of gullies. In field trips over the area we found where gullies divided fields in two or more parts making small irregular shaped fields as compared to the large easily worked fields of a few years ago. Studies are being made of methods of filling in these gullies. In the case of the larger gullies, it appears that dams of various kinds and brush or straw should be used to help hold the soil. The banks should be plowed in and the gully seeded to grass as soon as possible. If the season is not favorable for grass, wheat should be planted as it will grow under adverse conditions and greatly helps in holding the soil.

DEEP TILLAGE ON TERRACED AND UNTERRACED LAND
(Sub-Project No. S.E. 7.11)

Crop yields of winter wheat were taken of a deep tillage plot in field 4 which was described in the 1932 report. The ground was worked to a depth of 16 inches when the ground was dry and hard, following a crop of wheat in 1931. The field was all plowed the spring of 1932, fallowed, planted to winter wheat, and harvested the summer of 1933. There was no erosion the winter of 1931 and only a small amount in 1932 and no difference was apparent between the deep tillage plot and adjacent check plots. Crop yields were taken of sample plots along the east and west edges of the deep tillage plot and for adjoining check plots, the yields being as follows:

Yield of Winter Wheat in Bushels Per Acre

West side of Plot		East side of Plot	
Deep tillage	check	Deep tillage	check
19.5	50.3	15.4	32.1
28.1	38.1	20.6	16.4
31.0	46.8	26.9	44.2
32.1	46.7	58.7	56.0
59.9	43.9	52.0	53.2
50.8	43.4	58.2	54.6
54.2	53.7	53.2	54.9
51.7	42.2	55.7	48.1
59.7	59.4	56.4	53.8
62.1	58.8	50.6	47.3
49.2	52.9	43.6	
50.5	59.7	Avg. 44.7	46.1
53.1	52.1		
47.8	47.2		
45.8	41.6		
32.0	26.1		
	14.8		
Avg. 45.5	45.7		

1. Sample plots taken every 15 yards starting at lower edge of plot.

The difference in yield is too small to be significant and the deep tillage seemed to have no effect on the yield. Except for the upper slope where the soil is thin in places and the lower slope where the drainage is poor, this is an excellent piece of land. The average slope is about 14 per cent which is more gently sloping than most of the land. The average yield of winter wheat for field 4 was 41.7 bushels per acre (weight of wheat delivered to elevator).

On the control plots a 1/100 acre plot which was excavated and filled in with subsoil had much less erosion and an increased yield as compared to undisturbed subsoil. Following this 2 plots were selected where the subsoil was exposed in field 2 and the plots worked with the Killefer to a depth of 16 inches with the points 10 inches apart. The work was done in the spring when the ground was moist and the land was fallowed and planted

to winter wheat in the fall. The location was not favorable either for measuring runoff or for making observational comparisons of erosion. The crop yield will be measured in 1934 and if results are favorable, the tests will be continued on plots where the runoff and erosion can be measured.

TESTING OF HOLE DIGGING MACHINE
(Sub-Project No. S.E. 7.12)

The hole-digging cultivator was tested on various slopes at the Soil Erosion Station as given in the 1932 Annual Report. Due to the steepness of the slopes and the freezing and thawing, the holes were soon filled and according to observations of the areas, there was but slight difference in the amount of erosion where the hole-digging cultivator was used as compared to adjacent check areas. The crop yield was less where the cultivator was used.

On a cooperative project at the Adams Branch Substation at Lind, the cultivator conserved 1.0 inch more moisture and the yield of wheat was increased .9 bushels as compared to the check areas. Plans were made to continue this experiment the fall of 1933 but the station was practically discontinued and the experiment was not carried out. It is planned to make additional trials in the dryer, more gently rolling wheat section.

COMPARISON OF TILLAGE METHODS
(Sub-Project No. S.E. 7.13)

The purpose of this experiment is (1) to determine the best method of turning under stubble, legumes, or other plant residues, and to develop special machinery, if necessary, for use in doing this work; (2) to study the effect of the different plant residues on erosion, soil tilth, fertility, moisture conservation, and crop yield; and (3) to determine the

best time of turning under the plant residues.

A series of plots were started the spring of 1932 to study the effect of different summer fallow methods on erosion and crop yield. One area was plowed with a mold board plow and weeded with a rod weeder, and another area was disked with a regular 8 foot tandem disk and weeded with the same implement. Both areas were divided and the stubble burned on half. Where the ground was plowed, the stubble was practically all in one layer about six inches below the surface and where the disk was used the stubble was mixed with the surface soil to a depth of about five inches. The runoff and soil losses were not measured but from observation it appeared that the erosion was much less where the disk was used and the stubble not burned. There was no apparent difference in the amount of erosion for the other three plots, disked with stubble burned, plowed with stubble turned under, and plowed with stubble burned. The plots extended over a ridge including south slope, hilltop, and north slope. Yields of sample areas were taken for each condition, the results being as follows:

Tillage Plots: Yields of winter wheat in Bushels per Acre

	South slope		Hilltop		North slope	
	plowed	disked	plowed	disked	plowed	disked
stubble burned	28.1	25.0	23.8	28.9	45.0	60.2
" "	34.3	35.9	26.1	16.8	43.9	63.4
Average	31.2	30.5	24.9	22.9	44.5	61.8
Stubble unburned	26.8	30.3	31.4	26.3	48.2	56.6
" "	25.0	38.0	33.7	32.5	51.4	44.0
Average	25.9	34.2	32.6	29.4	49.8	50.3

The yields on the plots varied from 16.8 bushels per acre for one sample plot on the hilltop to 63.4 bushels per acre on the north slope.

There is no apparent trend in yield either in comparing plowing against disking or turning the stubble under as compared to where the stubble was burned. The variation between the two sample plots for each condition was frequently more than the difference between the averages. It is believed, however, that the results for this year show that the yield was practically the same for disked fallow as for plowed fallow and that the turning under of the stubble did not reduce the yield. The stubble was heavier on the slope below the plots and the turning under of this extremely heavy stubble might have a detrimental effect on the yield. The common practice is to allow the straw to run out of the combine in a windrow, and it is almost impossible to operate a plow through such a windrow in heavy stubble. A straw spreader on the combine would no doubt make the turning under of the stubble much easier.

The terraced land was fallowed in 1933 and as it is impossible to turn the furrow up the slope on the steep land, the moldboard plow could not be used to advantage. Therefore, a disk type of implement was used in place of the plow. The disk was of the tandem type with 22 inch disks spaced 9 inches apart. The disks in the front gang were all turned one way and the rear gang the opposite way. This implement would operate back and forth between terraces or on the terrace and do about the same work in either direction. The stubble was worked into the soil to some extent but some was left on top and not all the weeds and volunteer wheat were killed. The next tillage operation was made about four weeks later at about the time plowed fallow would be harrowed or weeded the first time.

The regular 8 foot tandem disk was used, 18 inch disks with 6 inch spacing. The peg-tooth harrow and rod weeder were used for later tillage operations the same as for plowed fallow. Wheat was planted in the fall and from all indications the yield will be equivalent to fallow which was plowed. The cost using the disk for the first two operations is believed to be about the same as for plowed fallow but the disk mixes the stubble with the soil and the erosion is noticeably less.

Strip-Seeding: The tillage operations are being studied in connection with strip seeding for summer fallow fields. Strip seeding in a summer fallow field is shown in Fig. 11. The gaps between the ends of the strips are to provide check areas for comparison to the strip seeding. In field practice each strip would be continuous. The strips should follow the contour in a general way although they may vary somewhat for convenience in working the field. In order to keep the cost at a minimum the spacing between strips should be uniform so summer tillage operations can be conducted without crossing strips.

The strips as shown consist of nine-foot drill widths of winter wheat which were seeded in the spring of the summer fallow season. The wheat makes considerable growth during the summer but the winter variety does not mature and will usually live over winter. The strips can be harvested the following summer with the remainder of the field which is planted in the fall to the same variety of winter wheat as was used in the strips. The effectiveness of this practice in erosion control has not yet been determined.

Fig. 11 Strip-seeding on steep slope on Soil Erosion Station. Single drill widths(9-foot) were seeded to winter wheat in the spring of the summer fallow season. The wheat makes considerable growth during the summer but the winter variety does not mature and will usually live over winter. The strips can be harvested the following summer with the remainder of the field which is planted in the fall to the same variety of winter wheat as was used in the strips.

WIND EROSION STUDIES

Wind erosion is a serious problem over several million acres in the drier sections of Washington, Oregon, and Idaho. The land might be classified in three general classes as: (1) Grazing land which has never been plowed, (2) Land once farmed but now abandoned due to wind erosion, (3) Land now under cultivation but subject to serious wind erosion.

The land under (2) and (3) had a good stand of native grasses before being plowed but these grasses come back very slowly when the land is abandoned.

A 160 acre tract of land located near Cunningham, Washington, in Latitude 46° 49'N. and Longitude 118° 49' W. has been furnished without cost for use in conducting studies on wind erosion. The adjoining 320 acres can also be obtained if needed. A survey and contour map of the 480 acres was made in 1933. The 160 acre tract and a portion of the adjoining tract is shown in Fig. 12. This tract of land was first farmed about 40 to 45 years ago. A house was built, and orchard and shade trees planted. The town of Cunningham which adjoins the property has two or three hotels, hardware stores, livery stables and the usual business establishments. At the present time considerable areas of land are abandoned, the 160 acres being abandoned from 10 to 15 years ago. The town of Cunningham now has but one business establishment, a combination store, filling station and post office. Most of the houses have been torn down.

In the fall of 1933, twelve plots were planted to grasses at the locations shown on the map of Fig. 12. The grasses used were crested wheat grass, slender wheat grass, and quincy grass. Different tillage methods were used in planting the grass as follows:

Broadcast seed with no tillage
Plant with single disk drill with no other tillage
Disk land and plant with single disk drill
Burn off vegetation before disking and planting.

This land is not valuable enough to justify much expense in obtaining a stand of grass and any method which is practical must be low in cost. The season following the planting of the grass was quite favorable but no results will be available until it is determined whether the plants survive the summer of 1934.

On areas which have continued under cultivation there are certain tillage practices which are very helpful in preventing wind erosion. The tillage should be conducted at a time when the moisture content of the soil is such that clods will be formed; also the stubble or vegetative growth should be left on the surface rather than turned under.

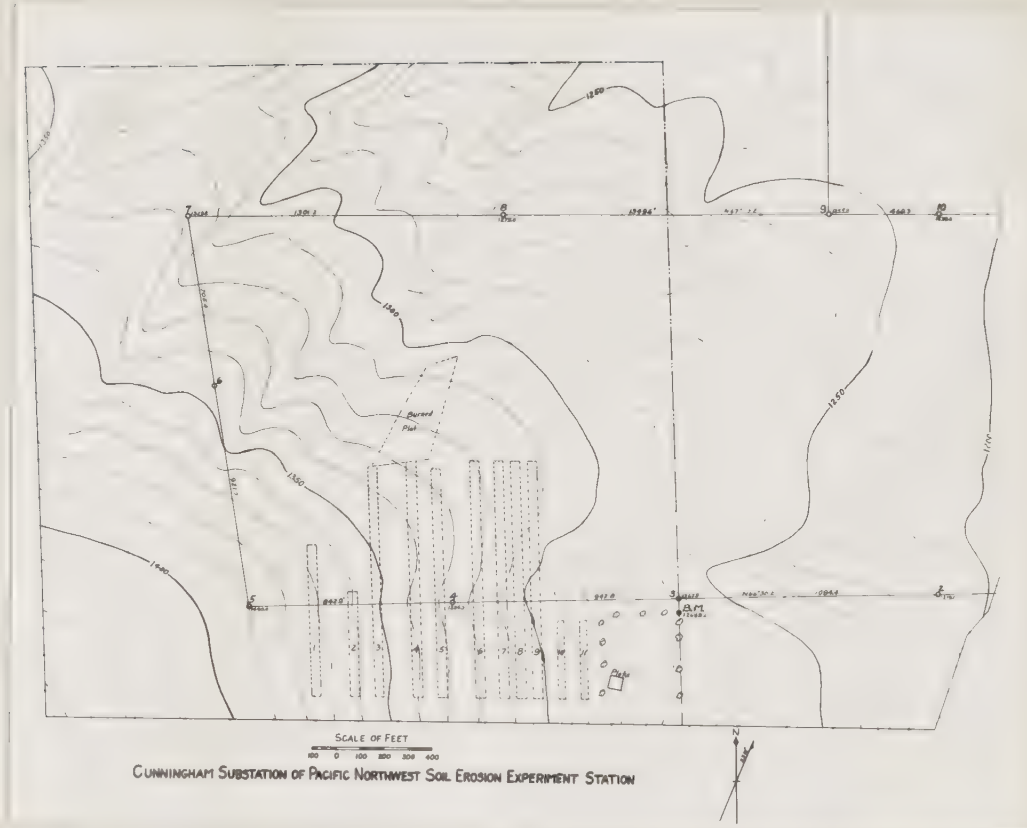


Fig. 12 Map of tract at Cunningham, Washington, used for studies of wind erosion.

DIVISOR USED ON 1/10 ACRE PLOTS AT THE
PACIFIC NORTHWEST SOIL EROSION STATION, PULLMAN, WASHINGTON

In designing a divisor for use on 1/10 acre plots, it was desired to obtain the same proportion of the flow for all heads, the desired aliquot being approximately 1/20 of the total flow. The season of erosion is during the winter and as the installation would be subject to snow and to freezing and thawing, it must be easily accessible for cleaning out snow and for checking the level of the flume from time to time. The original installations were to be handled out of Public Works funds and for this reason must be simple enough to be installed with the labor available and low enough in cost so the installations could be completed with the funds available. The divisor, as planned, can be quickly and easily cleaned and as the aliquot is removed in one stage the adjustment can be quickly checked and corrected if necessary.

The installation consists of (1) a screening compartment, which may also act as a settling chamber for part of the soil, (2) a flume which will spread the water uniformly at the outlet, (3) the divisor for taking off the aliquot, the divisor consisting of a slot opening .4 inches wide leading into a pipe to (4) the sample tank. Figures 13 and 14 show the different views of the installation.

(1) Screening Compartment: This compartment as shown in the photograph of Figure 13 is 30 x 96 inches by 12 inches deep at ends and 16 inches deep along sides of screen. The bottom has a fall of 1/4 inch per foot draining toward the flume and is flush with the flume. Considerable soil settled in the box, however, and as some soil will have to be handled

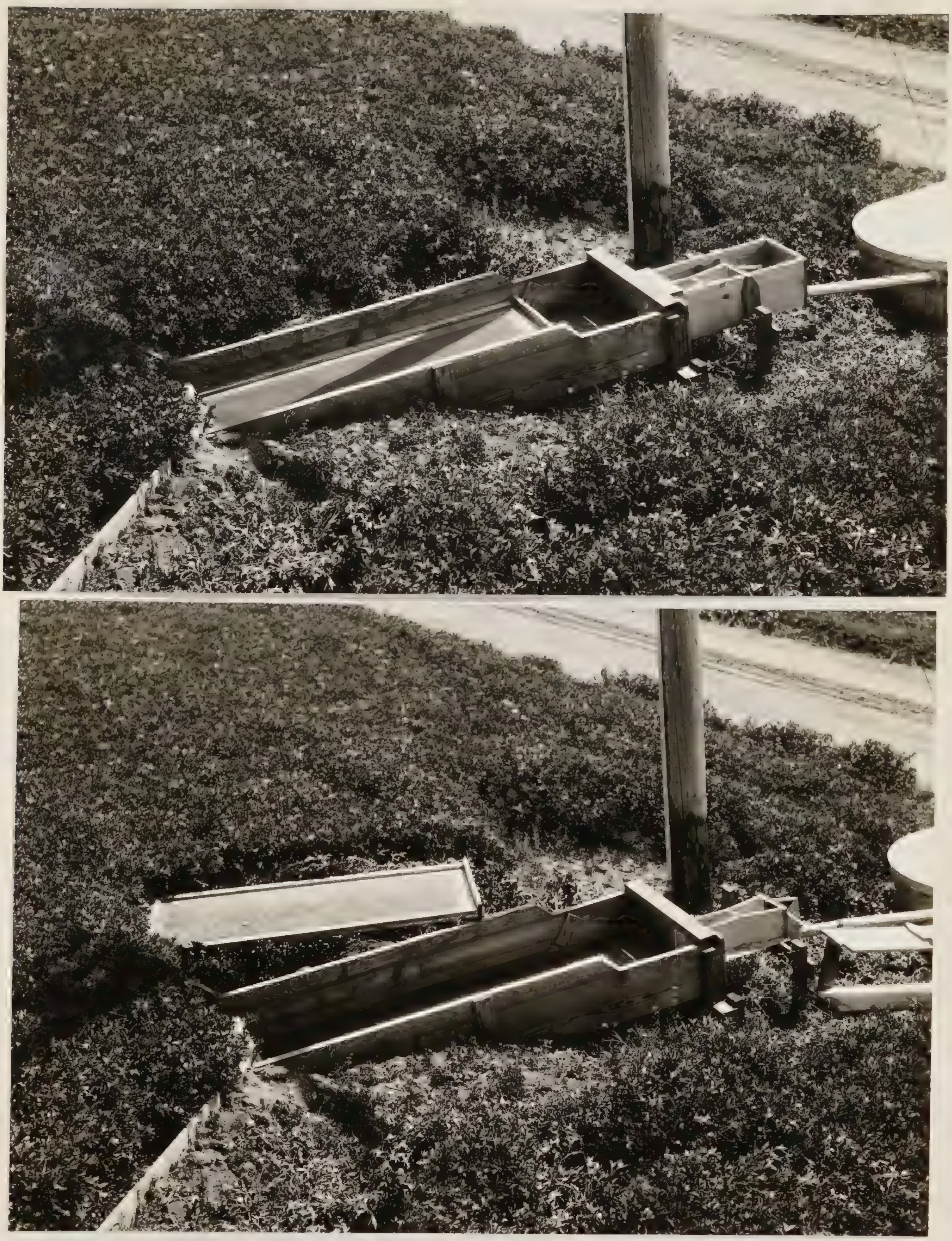


Fig. 13 (above) General view of installation for collecting 1/20 aliquot from field plots. Runoff enters at left running on to screen and from this compartment runs through flume where 1/20 aliquot is taken off at lower end of flume. The flume is protected from wind by a box (open top and bottom) around the sides and lower end.
(below) Same view with screen and box removed.

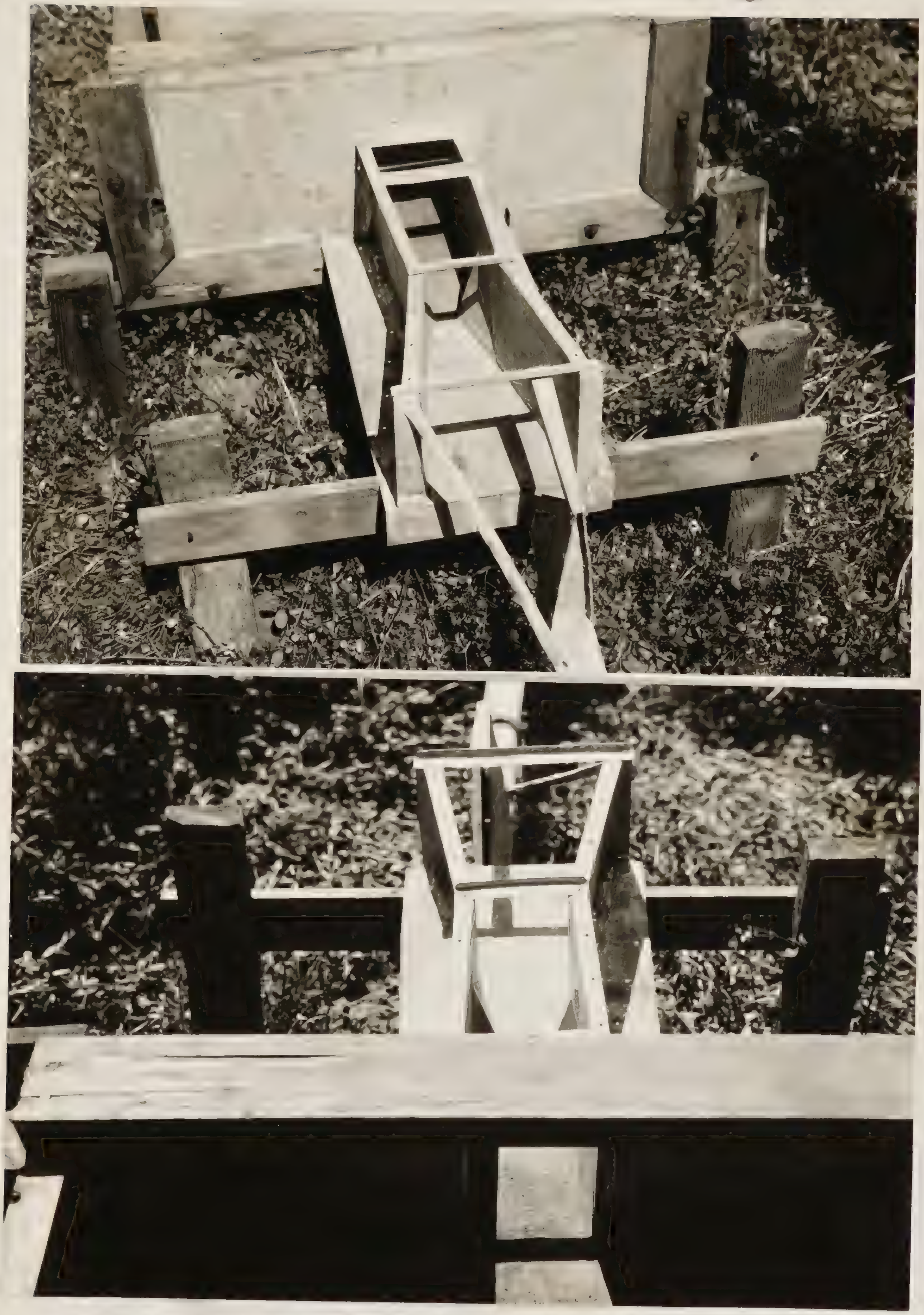


Fig. 14 Views of flume and divisor. (above) Looking at flume from outlet end. Note position of devise for taking of 1/20 aliquot. (below) Looking toward outlet of flume. Water enters flume at end of box which appears as a square light area in picture and on leaving flume 1/20 aliquot is taken off by an open slot onto which the water drops. 1/20 is conducted to sample tank and rest is wasted.

anyway it is believed a floor 3 to 6 inches below the floor of the flume might be better. The screen is the most important part and should be designed to remove all grass, roots, etc. The mesh should not be larger than 6 openings per inch. A 6 mesh screen 30 x 60 inches was used and there was no tendency to clog the screen. It is believed a second screen, either the same mesh or smaller, would remove what few roots get through the first and provide added protection against any errors caused by trash. This upper compartment might be varied to suit conditions the only essentials being that it remove all trash and provide an entrance to the flume.

(2) Flume: The flume is 24 inches long, 5 inches wide at entrance, 8 inches wide at discharge, and 7 inches deep. It is similar to the flumes used in the Bland Divisor. Views of flume are shown in Fig. 14. The laboratory facilities were not adequate to test the flume at the higher flow but the capacity is in excess of .3 cubic feet per second. The flume has a grade of 3/8 inches per foot or a drop of 3/4 inch from the upper to the lower end.

(3) Divisor: The divisor is attached to the lower end of the flume midway between the center and the edge. The divisor was attached at the 1/4 point rather than the center, as it was believed a more representative sample would be obtained in case there was a variation in the soil content between the center and edge of the flume outlet. The water falls on to the edges of the plates forming the slot and the section of water falling between the plates is collected in the sample tank. The opening between the parallel plates of the divisor is .4 inches and the plates are flared out

to provide clearance for the water after it has passed the edge. The plates were made of 18 gage galvanized steel and the upper edges were sharpened by filing on the outside. Fig. 14 shows how the plates are flared out to form an entrance into a $2\frac{1}{2}$ inch galvanized pipe connected to sample tank. The edges of the plates are $\frac{1}{2}$ inch below the floor of the flume at the point of connection and make a 45 degree angle with an extension of the line of the floor of the flume. A box, open top and bottom, surrounds the flume and divisor as shown in Fig. 13 and is used to prevent wind blowing the water to one side of the flume.

(4) Sample tank: Any watertight tank of the required capacity is satisfactory. Galvanized steel tanks with 1/4 pitch cone shaped lids were used on the installations.

Calibration: The flume was tested first with a small flow of water at the erosion station and later at the hydraulic laboratory at the State College of Washington. The results of the calibration were as follows:

CALIBRATION OF DIVISOR

(1) Flow in cu. ft./sec.	(2) time sec.	(3) Waste lbs.	(4) Aliquot lbs.	(5) Total lbs.	(6) Ratio (5)÷(4)	(7) Per cent Variation 1 to 20
.00301	217	37.50	2.25	39.75	17.7	11.5
.00552	130	42.375	2.375	44.75	18.9	- 5.5
.0074	300	133.0	6.94	139.94	20.2	- 1.0
.00838	360	179.0	9.19	188.19	20.5	- 2.5
.0156	197	182.0	10.00	192.0	19.2	+ 4.0
.0341	110	222.5	11.44	233.94	20.4	- 2.0
.0505	71	212.0	11.19	223.19	20.0	0.0
.0907	40	215.5	10.81	226.31	20.9	- 4.5
.123	29	212.5	10.69	223.19	20.9	- 4.5

The calibration was not entirely satisfactory as the flume was not

[illegible]

[illegible] ned by filling on the outside. Fig. 14 shows how the plates are flared out to form an entrance into a 2½ inch galvanized pipe connected to sample tank. [illegible] the flume at the point of connection and make a 45 degree angle with an extension of the line of the floor of the flume. A box, open top and [illegible]

(4) Sample tank: Any watertight tank of the required capacity is satisfactory. Galvanized steel tanks with 1/4 pitch cone shaped lids [illegible] on the installations.

Calibration: The flume was tested first with a small flow of water at [illegible] erosion station and later at the hydraulic laboratory at the State College of Washington. The results of the calibration were as follows:

CALIBRATION OF DIVISOR

(1) Flow in cu. ft./sec.	(2) Time sec.	(3) Water lbs.	(4) Silt? lbs.	(5) Total lbs.	(6) (5)÷(4)	(7) Variation 1 to ?
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	42.37	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	179.0	9.19	188.19	20.5	- 2.5
[illegible]	[illegible]	182.0	10.00	192.0	19.2	+ 4.0
.0541	110	222.5	11.44	233.94	20.4	- 2.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.0907	40	215.5	10.81	226.31	20.9	- 4.5
[illegible]	29	212.5	10.65	223.19	20.9	- 4.5

[illegible] calibration was not entirely satisfactory as the flume was not

set rigidly, also the upper compartment was very small causing surging at the entrance to the flume. The maximum head obtained in the calibration was less than half the capacity of the flume. The largest error was at the lowest head with a flow about 1.3 gallons per minute which is an extremely low rate of runoff for a 1/10 acre plot. The errors in calibration are believed to have caused the per cent variation to be irregular. If the proportion, for example, became smaller for the higher heads this could be overcome by widening the slot toward the upper end.

There was no difficulty due to freezing and thawing as the divisor and flume were 6 to 12 inches off the ground. The flume was fastened to cross pieces and posts as shown in Fig. 14. The lower end of the screen compartment was also off the ground at most of the installations. A slight movement of the screening compartment would probably not affect the results as long as the lower end of the flume was held level.

The flume size selected is believed to be adequate for runoff of a 1/10 acre plot at Pullman, Washington. It is quite possible it might not be large enough in regions of more intense rainfall. The same general idea could be used with larger or smaller flumes and if a smaller aliquot was desired, two stages could be used which, if the first stage was 1/20 and the second 1/10, the aliquot would be 1/20 x 1/10 or 1/200. A suitable screening compartment is essential to the success of this method and for this reason, it is limited to comparatively small areas, probably less than one acre.

TESTS OF SPECIAL DIVISOR

On the larger watersheds, of five to fifteen acres or more, an excessively large silt box is necessary, which is expensive both in original

cost and maintenance. Two stations of about 15 acres each and one of 68 acres have been installed at the Pullman station for recording runoff and soil losses. Hand sampling has been used to determine the soil content of the runoff water. An attempt has been made to develop a simple aliquot sampler for use on such installations. The tests were conducted on a device for taking an aliquot out of the side of the flume at a point 1/3 of the distance from the upper end to the throat.

The first tests were made using 1/4 inch holes through a plate set in the side of the flume and allowing the plate to project into the flume about one-half inch. It was found, however, that the flow was practically the same with the plate flush with the side of the flume and all future tests were made with the plate flush. Various trash deflectors were tried and a screen was finally decided on as being most satisfactory. With the 1/4 inch holes there was considerable variation in the aliquot for heads below about .35 feet and in order to overcome this objection further tests were conducted using 3/16 inch holes. A six-inch Parshall flume was used in the tests as facilities were not available for conducting tests with the larger flumes. It is believed the same device would work on a larger flume and would give, for example, approximately 1/4 the aliquot for the two-foot flume as compared to the six-inch flume. The aliquot using 3/16 inch holes would be fairly constant for heads above about .18 feet but the aliquot would be larger for heads from .04 to .18 feet. The flow is low, however, for the lower heads and during periods of considerable runoff it is believed the per cent error would be very small. An automatic gate at the bottom

hole, operated by a float, could be made to open the hole gradually as the head increased, from an almost closed position at .04 to an open position at .18 feet head. The final tests were as follows:

TEST OF DIVISOR

Holes: 3/16 inches diameter spaced .04, .235, .370, .505, .640, .77, .90, 1.03, and 1.16 feet up from floor of six-inch flume. Holes are 1/3 of distance between upper end and throat of flume. Screens were used over holes to prevent trash from clogging holes.

(1) Head in flume	(2) Flow 6" flume	(3) Aliquot	(4) Proportion (2) ÷ (3)	
feet	sec. ft.	sec. ft.		
.062	.025	.000167	150	Bottom hole flowing
.094	.049	.000247	199	" " "
.14	.09	.000309	291	" " "
.167	.12	.000346	347	" " "
.22	.18	.000402	472	" " "
.287	.29	.000722	402	Two holes flowing
.37	.43	.000946	455	Two holes flowing
.54	.78	.00193	404	Four holes flowing
.708	1.19	.00286	416	Five holes flowing
1.104	2.42(est)	.00538	450	Eight holes flowing

Flow of Individual Holes

Head in flume (feet)	Head on Hole (feet)	Flow (sec.ft.)	
.287	.247	.000506	Bottom hole .04' above floor
.375	.335	.000596	" " " " "
.540	.500	.000745	" " " " "
.708	.668	.000888	" " " " "
1.104	1.064	.001115	" " " " "
.287	.052	.000216	Second hole .235' above floor
.375	.140	.000350	" " " " "
.530	.295	.000532	" " " " "
.708	.473	.000678	" " " " "
1.104	.869	.000915	" " " " "
.537	.167	.000365	Third hole .37' above floor
.708	.338	.000558	" " " " "
1.104	.734	.000824	" " " " "
.537	.032	.000155	Fourth hole .505' above floor
.708	.203	.000413	" " " " "
1.104	.599	.000745	" " " " "
.708	.068	.000214	Fifth hole .64' above floor
1.104	.494	.000642	" " " " "
1.104	.334	.000524	Sixth hole .77' above floor
1.104	.204	.000393	Seventh hole .90' above floor
1.104	.074	.000231	Eighth hole 1.03' above floor

The plotted results of the tests are shown in Fig. /. The aliquot averages one part in 430 for heads above about .18 feet. There is slight fluctuation in the aliquot but as the head is variable, it is believed this will not be a source of error. The spacing of holes could be changed if it were desired to increase or decrease the aliquot. Tests were made of the flow for individual holes as shown in Table A and Fig. /4 and the flow can be calculated for different spacing of holes.

The test installation is shown in Fig. 15 (a) with the divisor in place. In Fig. 15 (b), (c), and (d) are different views of the divisor. The holes were drilled through an 18 gage galvanized plate, using a drill slightly smaller than 3/16 inch and were then reamed to 3/16 inch. This gave smoother, more uniform holes than if a 3/16 inch drill were used. Individual screens were used over each hole as shown in Fig. 15. The screens were made of 8-mesh hardware cloth soldered over $\frac{3}{4}$ x 2" holes cut in a piece of galvanized steel. This steel sheet with the screens slides behind guides attached to the sheet with the 3/16 inch holes. It can be easily removed for cleaning and by raising and lowering will shear off material which might be in any hole, thus making rapid cleaning possible during times of runoff. Each screen is $\frac{3}{4}$ x 2 inches and sets out $\frac{1}{2}$ inch from the 3/16 inch hole. There was no tendency for the 3/16 inch holes to clog and the screen clogged only slightly on the upstream side and did not affect the flow as determined by a 48 hour test with water carrying a considerable amount of silt and organic material. None of the holes were clogged at the end of the 48 hour test. There has not yet been an opportunity to test this divisor on a field

The plotted results of all tests are shown in Fig. [illegible]. The aliquot [illegible] part in 450 for heads above about .18 feet. There is slight fluctuation in the aliquot but as the head is variable, it is believed this will not be a source of error. The spacing of holes could be changed if it were desired to increase or decrease the aliquot. Tests were made of the flow for individual holes as shown in Table 4 and Fig. 16 and the flow can be calculated for different spacing of holes.

[illegible] is shown in Fig. [illegible] [illegible] [illegible] The holes were drilled through an 18 gage galvanized plate, using a drill slightly smaller than 3/16 inch and were then reamed to 3/16 inch. This gave smoother, more uniform holes than if a 3/16 inch drill were used. Individual screens were used over each hole as shown in Fig. [illegible]. The screens [illegible] [illegible] attached to the sheet with the 3/16 inch holes. It can be easily [illegible] and by raising and lowering will shear off material which might be [illegible] [illegible] screen is $\frac{1}{2}$ x 2 inches and sets out $\frac{1}{8}$ inch from the 3/16 inch hole. [illegible] [illegible] [illegible] [illegible] material. None of the holes were clogged at the end of the 48 hour tests. There has not yet been an opportunity to test [illegible]

(a)

(b)

(c)

(d)

Fig. 15 (a) View of flume with divisor in place.

(b) Side view of divisor showing well at back for catching flow from 3/16" holes.

(c) Front view of divisor.

(d) Divisor with screen removed. Screen slides behind guides and is easily removed.

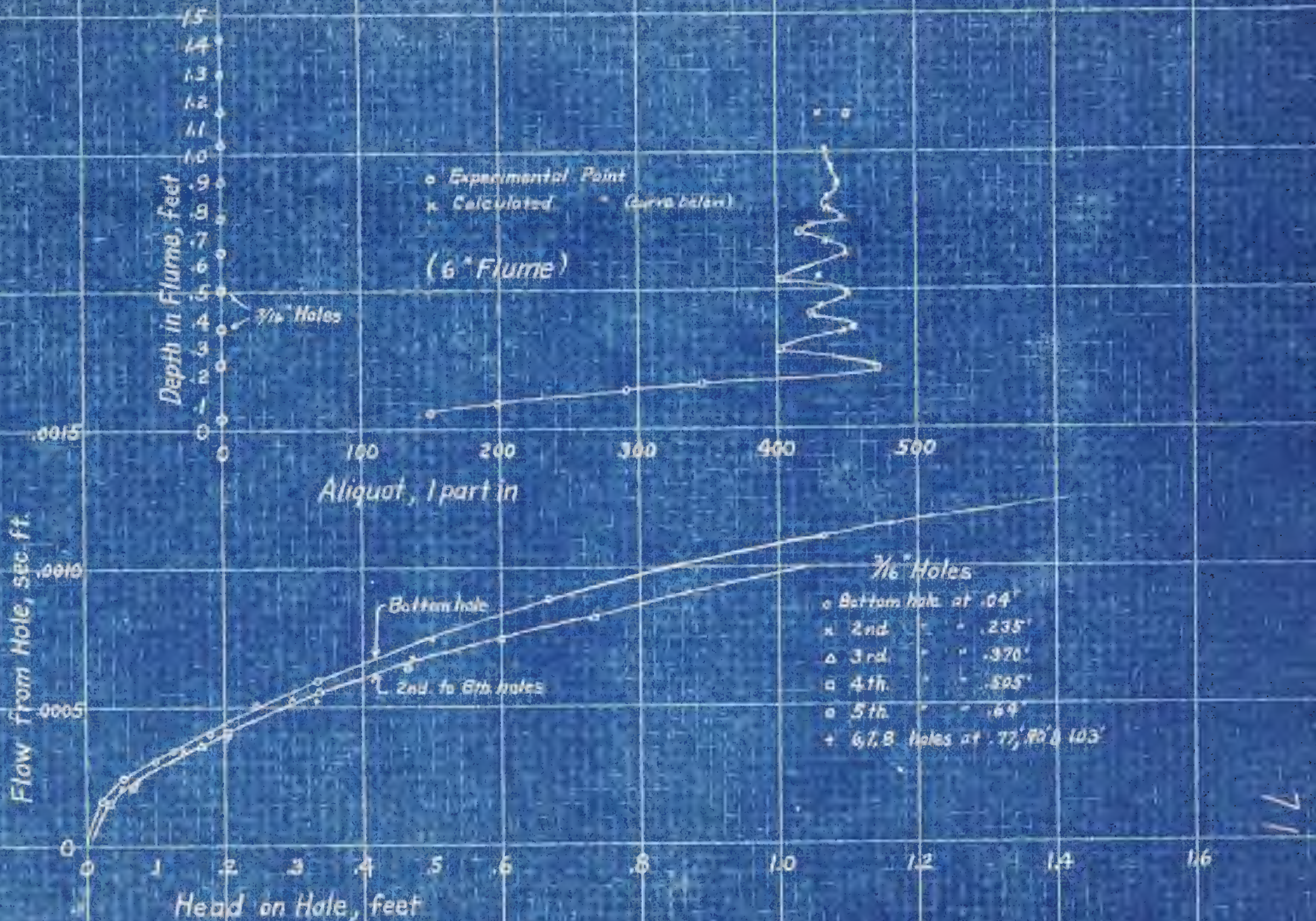


FIG. 16 TEST OF DIVISOR

installation. The water from the 3/16 inch holes is collected in a well attached behind the holes and is conducted to a sample tank of the required capacity. With the spacing of holes used in the tests the aliquot for different size flumes would be approximately as follows: 6-inch flume 1:430, 12-inch flume 1:860, 24-inch flume 1:1720, 48-inch flume 1:3440.

No tests were made of the effect of the divisor on the capacity of the flume. Practically no eddies are formed, however, and from observation it would appear that the divisor does not affect the capacity of the flume. A few tests were made to compare the silt content of the aliquot to that in the flume. In taking samples one sample was taken of the aliquot while a sample was caught simultaneously at the outlet of the flume.

Date	Head in Flume	Soil in Sample	Location	Remarks
	feet	lbs./cu.ft.		
Feb. 13	.58	.90	Divisor	1/4" holes--no screen
Feb. 13	.58	.82	Flume	" " " "
Feb. 14	.10	.45	Divisor	" " " "
Feb. 14	.10	.44	Flume	" " " "
Feb. 15	-	.35	Divisor	3/16" holes--metal trash deflector
Feb. 15	-	.36	Flume	" " " " "
Mar. 31	.54	.056	Divisor	3/16"holes--with screen
Mar. 31	.54	.063	Flume	" " " "
Mar. 31	.75	.062	Divisor	" " " "
Mar. 31	.75	.060	Flume	" " " "

It was expected that the soil content of the aliquot would be less than the sample from the flume. This is not the case with the tests, however, as the divisor sample is high the same number of times as the flume sample. These few samples are not considered as conclusive, however, and for best results it is believed the soil content should be checked when there is run-off from field installations.

SUMMARY

The steeply rolling wheat country known as the Palouse Region has now been in cultivation about fifty years. Many slopes of fifty per cent are in cultivation and slopes of 25 to 35 per cent are common.

The average yield of wheat is excellent even though nearly all fields now have some low producing areas, where the subsoil has been exposed by erosion.

The average annual rainfall at a Weather Bureau station three miles from the Erosion Station is 20.73 inches. The normal for the seven months of April to October is 8.22 inches and for the other five months is 12.51 inches.

The erosion occurs during the season from November to March except for infrequent summer rains of high intensity. Such summer rains have occurred at several points during the last three years but are believed to be of minor importance as compared to winter erosion problems.

In December 1933, there was rain every day but one for the 18 days from December 5 to 22, the total being 7.53 inches, and on the last day of this period a rain of .79 inches fell with the highest intensity so far recorded for the Station. There was serious erosion on several days during this period and especially on December 22. The maximum rate of rainfall so far recorded was .72 inches per hour for a five minute period and .30 inches per hour for a 30 minute period.

Experimental terraces were constructed on slopes of from 12 to 32 per cent.

The cropping system of wheat--summer fallow is most widely used in the Palouse Region and was adopted for the terraced land.

Graded terraces 780 feet long with vertical spacings from 15 to 35 feet were constructed on land slopes of 20 to 28 per cent. The 35 foot vertical spacing was too great and an intermediate terrace was built. Soil and slope differences caused greater differences in erosion for this experiment than the variation in vertical spacing. The annual soil losses varied from 1.82 to 5.11 tons per acre. The soil loss was 16 to 200 times greater for the winter season following the planting of wheat on summer fallow as compared to land covered by wheat stubble during the winter season.

Soil losses were measured for graded terraces with 15 feet vertical spacing, grades of 12 inches per 100 feet, and lengths of 400, 780 and 2274 feet. The average annual soil loss was 1.87 tons per acre for a terrace 400 feet long, 1.82 tons for a 780 foot terrace, and 3.94 tons for a 2274 foot terrace.

Graded terraces 780 feet long and with a fall of 12 inches per 100 feet had average annual soil losses of .57 tons per acre for a 14.5 per cent slope, 1.82 tons for a 20.0 per cent slope, 7.20 tons for a 23.5 per cent slope, and 5.11 tons for a 27.6 per cent slope. The apparent inconsistency of the latter two is believed to be due to soil conditions. In general, however, the soil loss increases as the slope increases.

Erosion and runoff were measured for terraces with grades of level, 6, 12, 18, and 24 inches fall per 100 feet. The soil loss was 1.28 tons per acre for the level terrace, 2.90 tons for a grade of 6 inches per 100 feet, 7.20 tons for a 12 inch grade, 10.36 tons for an

18 inch grade, and 13.67 tons for a 24 inch grade. The 6 and 12 inch grades gave best results from the standpoints of operation and soil losses.

Level terraces with closed ends impounded water continuously for four and one-half months and did not have capacity to hold all the runoff. Provision should be made to waste the excess runoff either by a suitable outlet ditch or by tile drainage.

Terraces on land slopes of 20.0 per cent and less were lowered an average of 1.7 inches by summer tillage of fallow land and terraces on land slopes more than 10.0 per cent were lowered an average of 2.9 inches. Terraces should be maintained by making one or two trips along the upper side each season the land is tilled.

The tillage machinery used in the region cannot operate successfully across terraces on steep slopes. Best results were obtained by operating parallel to the terraces and using machinery which can be operated in either direction along a slope.

Measurements of ground elevations were taken every six inches along 8 profile lines and these measurements will be repeated the fall of 1934 and at later intervals to study the rate of soil movement for terraced and unterraced land.

The average annual soil loss from two unterraced watersheds was 16.8 tons per acre as compared to an average of 3.20 tons for representative terraces.

Check dams were built in terrace outlet ditches after which the

ditches were seeded to a sod-forming grass.

Observations were made of erosion, and crop yields were taken on land fallowed with the mold board plow as compared to disked fallow; the stubble being burned for part of each condition. The erosion was less where the disk was used and the stubble not burned. There was no significant difference in the crop yields.

Grass seeding on an area subject to wind erosion was started at Cunningham, Washington. A map was completed of the tract at Cunningham.

TABLE NO. 10. EROSION AND RUN-OFF FROM GRADED TERRACES
WITH DIFFERENT VERTICAL SPACING

Date		Maximum Rates of Rainfall					Total	Maximum Rates of Run-off								Total Run-off				Soil Loss Per Acre				Remarks
		5 Min.	10 Min.	15 Min.	20 Min.	30 Min.	Rain-fall	Terrace No. 3		Terrace No. 3A		Terrace No. 4		Terrace No. 5		Ter. 3	Ter. 3A	Ter. 4	Ter. 5	Ter. 3	Ter. 3A	Ter. 4	Ter. 5	
1933		inches per hr	inches per hr	inches per hr	inches per hr	inches per hr	inches	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	inches	inches	inches	inches	tons	tons	tons	tons	
January	4						.10[1]	0	0	.038	.036	.008	.004	0	0	0	.28	.02	0	0	.019	0	0	Ground cover
"	5						.07	.018	.015	.07	.067	.013	.007	0	0	.05	.59	.03	.02	.002	.040	0	0	wheat stu
"	7	.12	.12	.12	.12	.12	.55	.013	.011	.024	.023	.013	.007	.013	.010	.06	.17	.03	.07	.006	.023	.002	.004	"
"	8	.16	.16	.16	.12	.08	.26	0	0	.013	.012	0	0	.013	.010	0	.14	0	.01	0	.019	0	.001	"
"	9						.08	0	0	.008	.008	0	0	0	0	0	.01	0	0	0	.019	0	0	"
February	21						0	0	0	.001	.001	0	0	0	0	0	.01	0	0	0	0	0	0	"
"	22	.12	.09	.08	.07	.07	.22	.07	.057	.038	.036	.10	.054	.18	.142	.17	.21	.57	.40	.005	.009	.015	.009	"
"	23						.66[1]	0	0	.008	.008	.08	.043	0	0	0	.01	.14	0	0	0	.004	0	"
March	1						0	.038	.031	.024	.023	.14	.075	.008	.006	.11	.20	.27	.03	.009	.205	.034	.003	"
"	2	.24	.20	.20	.18	.16	.30	.06	.049	.013	.012	.09	.048	.013	.010	.06	.06	.08	.06	.005	.118	.010	.005	"
"	3						0	.013	.011	.004	.004	.008	.004	.013	.010	.02	.03	.01	.02	.002	.059	.002	.005	"
Total January 1 to March 3																.47	1.71	1.15	.61	.029	.511	.067	.027	"
March 4 to October 28																No Run-off								
October	29						0	0	0	-	-	0	0	0	0	0	.01	0	0	0	.004	0	0	Winter Wheat
November	2	.30	.24	.22	.20	.18	.91	.038	.031	.038	.036	0	0	0	0	.05	.10	0	0	.068	.039	0	0	Fallow
"	3	.48	.36	.28	.27	.22	.50	.15	.122	.16	.155	.046	.025	0	0	.12	.38	.02	.06	.102	.220	.021	.042	"
December	6	.48	.36	.32	.21	.18	1.82	.38	.309	.28	.267	.31	.166	.16	.126	.46	.64	.19	.15	.931	1.087	.286	.222	"
"	8						.20	.031	.025	0	0	0	0	0	0	.04	0	0	0	.044	0	0	0	"
"	9	.21	.18	.18	.18	.18	1.53	.12	.098	.09	.086	.12	.064	.06	.047	.83	.87	.53	.33	.925	.951	.400	.191	"
"	10	.12	.09	.08	.08	.08	.31	.11	.089	.08	.076	.14	.075	.05	.043	.12	.18	.10	.04	.134	.197	.082	.023	"
"	11	.20	.12	.12	.12	.10	.16	.031	.025	.031	.030	.018	.010	.004	.003	.03	.07	.02	.01	.002	.080	.004	.005	"
"	12						.17	.038	.031	.031	.030	.024	.013	0	0	.05	.02	.03	0	.004	.009	.006	0	"
"	13						.13	.22	.179	.11	.105	.19	.102	.05	.043	.07	.05	.04	.03	.125	.042	.054	.028	"
"	14	.12	.12	.08	.08	.06	.10	.05	.044	.038	.036	.046	.025	.008	.006	.04	.05	.02	.02	.035	.021	.010	.008	"
"	18	.18	.12	.10	.10	.10	.65	.07	.057	.054	.051	.08	.043	.018	.014	.27	.38	.19	.10	.122	.142	.072	.021	"
"	19	.05	.05	.05	.05	.02	.13	.07	.057	.038	.036	.06	.032	.018	.014	.10	.16	.09	.04	.064	.064	.034	.008	"
"	20						.25	.05	.044	.038	.036	.06	.032	.024	.019	.15	.17	.09	.04	.238	.064	.034	.013	"
"	21	.24	.20	.18	.18	.16	.18	.28	.228	.18	.172	.34	.182	.160	.126	.14	.13	.10	.06	.230	.050	.122	.102	"
"	22	.72	.42	.28	.21	.18	.79	.58	.471	.43	.410	.45	.241	.230	.181	.47	.57	.40	.33	1.210	1.122	.770	.476	"
"	23						0	.38	.309	.26	.248	.29	.155	.180	.142	.05	.21	.04	.03	.299	.471	.158	.064	"
"	24						0	0	0	.004	.004	0	0	0	0	0	.10	0	0	0	.022	0	0	"
"	25-31						.60[1]	0	0	.001	.001	0	0	0	0	0	.14	0	0	0	.014	0	0	"
Total October 29 to December 31																2.99	4.23	1.86	1.24	4.533	4.599	2.053	1.203	"
Total for Year 1933																3.46	5.94	3.01	1.85	4.562	5.110	2.120	1.230	

Terrace No.	Drainage Area	Land Slope	Vertical Spacing	Length	Grade
	Acres	per cent	feet	feet	inches per 100 feet
3	1.22	27.8	20.0	780	12
3A	1.04	27.6	15.0	780	12
4	1.85	23.6	25.0	780	12
5	1.26	20.0	15.0	780	12

1. Snow

TABLE NO. 11. EROSION AND RUN-OFF FROM GRADED TERRACES OF DIFFERENT LENGTHS

Date	Maximum Rates of Rainfall: 5 Min.	10 Min.	15 Min.	20 Min.	30 Min.	Total Rain-fall	Maximum Rates of Run-off: Terrace No. 2		Terrace No. 5		Terrace No. 6		Total Run-off: Ter. 2	Ter. 5	Ter. 6	Soil Loss per Acre: Ter. 2	Ter. 5	Ter. 6	Remarks
1933	inches per hr	inches per hr	inches per hr	inches per hr	inches per hr	inches	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	inches	inches	inches	tons	tons	tons	
January 4						.10[1]	.002	.004	0	0	.12	.025	.03	0	.14	.001	0	.003	Ground cover of winter wheat stubble
" 5						.07	.028	.050	-	-	.10	.021	.22	.02	.21	.008	0	.004	
" 7	.12	.12	.12	.12	.12	.55	.007	.012	.013	.010	.08	.017	.12	.07	.18	.005	.004	.006	"
" 8	.16	.16	.16	.12	.08	..26	.002	.004	.013	.010	.03	.006	.01	.01	.07	0	.001	.002	"
" 9						.08	0	0	0	0	.03	.006	0	0	.04	0	0	.001	"
February 21						0	.001	.001	0	0	.01	.002	.02	0	.03	0	0	0	"
" 22	.12	.09	.08	.07	.07	.22	.016	.028	.18	.142	.20	.042	.25	.40	.26	.005	.009	.005	"
" 23						.66[1]	0	0	0	0	.03	.006	0	0	.02	0	0	0	"
" 26						0	0	0	0	0	.03	.006	0	0	.01	0	0	0	"
" 28						.21	.013	.023	0	0	0	0	.05	0	0	.001	0	0	"
March 1						0	.007	.012	.008	.006	.10	.021	.06	.03	.15	.007	.003	.004	"
" 2	.24	.20	.20	.18	.16	.30	.016	.028	.013	.010	.40	.085	.05	.06	.29	.007	.005	.008	"
" 3						0	.002	.004	.013	.010	.16	.034	.03	.02	.20	.003	.005	.005	"
" 4						0	0	0	0	0	.04	.008	0	0	.04	0	0	.003	"
" 5						0	0	0	0	0	.02	.004	0	0	.03	0	0	.002	"
" 7						.25[1]	0	0	0	0	.02	.004	0	0	.02	0	0	.001	"
" 8						0	0	0	0	0	.04	.008	0	0	.03	0	0	.002	"
" 9-12						.37[1]	0	0	0	0	.03	.006	0	0	.05	0	0	.012	"
Total January 1 to March 12													.84	.61	1.77	.037	.027	.058	"
March 13 to November 2													No Run-off						
November 3	.48	.36	.28	.27	.22	.50	.020	.035	-	-	.06	.013	.04	.06	.01	.009	.042	.009	Winter wheat on summer fallow
December 6	.48	.36	.32	.21	.18	1.82	.037	.066	.16	.126	.49	.104	.15	.15	.25[2]	.212	.222	.354	
" 9	.21	.18	.18	.18	.18	1.53	.037	.066	.06	.047	.95	.201	.48	.33	.80[3]	.234	.191	.866	"
" 10	.12	.09	.08	.08	.08	.31	.037	.066	.05	.043	.23	.049	.09	.04	.10	.043	.023	.108	"
" 11	.20	.12	.12	.12	.10	.16	.004	.008	.004	.003	.06	.013	.03	.01	.02	.009	.005	.010	"
" 12						.17	.010	.018	0	0	0	0	.02	0	0	.004	0	0	"
" 13						.13	.037	.066	.05	.043	.14	.030	.03	.03	.03	.024	.028	.028	"
" 14	.12	.12	.08	.08	.06	.10	.016	.028	.008	.006	.04	.008	.04	.02	.02	.016	.008	.006	"
" 18	.18	.12	.10	.10	.10	.65	.028	.050	.018	.014	.12	.025	.35	.10	.08	.038	.021	.021	"
" 19	.03	.03	.03	.02	.02	.13	.028	.050	.018	.014	.12	.025	.26	.04	.03	.068	.008	.008	"
" 20						.25	.033	.058	.024	.019	.16	.034	.21	.04	.04	.233	.013	.013	"
" 21	.24	.20	.18	.18	.16	.18	.095	.168	.16	.126	.54	.114	.07	.06	.10	.078	.102	.102	"
" 22	.72	.42	.28	.21	.14	.79	.222	.393	.23	.181	.54	.114	.55	.33	.39	.842	.476	.476	"
" 23						0	.162	.287	.18	.142	.28	.059	.08	.03	.03	.192	.064	.064	"
Total November 3 to December 31													2.40	1.24	1.90	2.002	1.203	2.065	"
Total for Year 1933													3.24	1.85	3.67	2.039	1.230	2.123	

Terrace No.	Drainage Area	Land Slope	Vertical Spacing	Length	Grade
	Acres	per cent	feet	feet	inches per 100 feet
2	.56	22.6	15.0	400	12
5	1.26	20.0	15.0	780	12
6	4.68	16.2	14.7	2274	12

1. Snow
2. Squirrel hole under terrace 1500 feet from outlet was plugged 9:30 A.M.
3. Squirrel hole under terrace 300 feet from outlet plugged 10:30 A.M.

TABLE NO. 12. EROSION AND RUN-OFF FROM GRADED TERRACES
ON DIFFERENT LAND SLOPES

Date	Maximum Rates of Rainfall					Total	Maximum Rates of Run-off								Total Run-off				Soil Loss Per Acre				R-e-m-a-r
	5 Min.	10 Min.	15 Min.	20 Min.	30 Min.	Rain-fall	Terrace No. 7		Terrace No. 5		Terrace No. 17		Terrace No. 3A		Ter. 7	Ter. 5	Ter. 17	Ter. 3A	Ter. 7	Ter. 5	Ter. 17	Ter. 3A	
1933	inches per hr	inches per hr	inches per hr	inches per hr	inches per hr	inches	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	inches	inches	inches	inches	tons	tons	tons	tons	
January 4						.10[1]	.08	.038	0	0	.004	.004	.038	.036	.28	0	.02	.28	.002	0	.001	.019	Ground cov
" 5						.07	.29	.138	-	-	.008	.009	.07	.067	.86	.02	.02	.59	.006	0	.001	.040	Wheat
" 6						0	.038	.018	0	0	0	0	0	0	.18	0	0	0	.001	0	0	0	"
" 7	.12	.12	.12	.12	.12	.55	.29	.138	.013	.010	.001	.001	.024	.023	1.13	.07	.05	.17	.020	.004	.005	.023	"
" 8	.16	.16	.16	.12	.08	.26	.12	.057	.013	.010	0	0	.013	.012	.73	.01	0	.14	.013	.001	0	.019	"
" 9						.08	.018	.009	0	0	0	0	.008	.008	.13	0	0	.01	0	0	0	.019	"
February 21						0	0	0	0	0	0	0	.001	.001	0	0	0	.01	0	0	0	0	"
" 22	.12	.09	.08	.07	.07	.22	.08	.038	.18	.142	.004	.004	.038	.036	.28	.40	.03	.21	.007	.009	.003	.009	"
" 23						.66[1]	.008	.004	0	0	0	0	.008	.008	.02	0	0	.01	0	0	0	0	"
March 1						0	.018	.009	.008	.006	.004	.004	.024	.023	.06	.03	.02	.20	.001	.003	.007	.205	"
" 2	.24	.20	.20	.18	.16	.30	.25	.119	.013	.010	.001	.001	.013	.012	.18	.06	.01	.06	.002	.005	.003	.118	"
" 3						0	.08	.038	.013	.010	0	0	.004	.004	.14	.02	0	.03	.001	.005	0	.059	"
" 7						.25[1]	.013	.006	0	0	0	0	0	0	.01	0	0	0	0	0	0	0	"
" 8						0	.06	.028	0	0	0	0	0	0	.08	0	0	0	.001	0	0	0	"
" 9						.34[1]	.024	.011	0	0	0	0	0	0	.03	0	0	0	0	0	0	0	"
" 10-11						0	.05	.026	0	0	0	0	0	0	.14	0	0	0	.005	0	0	0	"
Total January 1 to March 11															4.25	.61	.15	1.71	.059	.027	.018	.511	"
March 12 to October 28															No Run-off								
October 29						0	0	0	0	0	0	0	-	-	0	0	0	.01	0	0	0	.004	Winter whe
" 31	.36	.24	.22	.21	.16	.73	0	0	0	0	-	-	0	0	0	0	.01	0	0	0	.014	0	Fallow
November 2	.30	.24	.22	.20	.18	.91	0	0	0	0	.06	.065	.038	.036	0	0	.16	.10	0	0	.218	.039	"
" 3	.48	.36	.28	.27	.22	.50	0	0	-	-	.15	.162	.16	.153	0	.06	.28	.38	0	.042	.378	.220	"
December 6	.48	.36	.32	.21	.18	1.82	0	0	.16	.126	.48	.517	.28	.267	0	.15	.65[3]	.64	0	.222	2.235	1.087	"
" 7						0	0	0	0	0	.013	.014	0	0	0	0	.06	0	0	0	.240	0	"
" 9	.21	.18	.18	.18	.18	1.53	.14	.066	.06	.047	.09	.097	.09	.086	.34[2]	.33	.85	.87	.160	.191	1.590	.951	"
" 10	.12	.09	.08	.08	.08	.31	.024	.011	.05	.043	.08	.086	.08	.076	.02	.04	.20	.18	.009	.025	.366	.197	"
" 11	.20	.12	.12	.12	.10	.16	0	0	.004	.003	.031	.033	.031	.030	0	.01	.08	.07	0	.005	.062	.080	"
" 12						.17	0	0	0	0	.046	.050	.031	.030	0	0	.06	.02	0	0	.046	.009	"
" 13						.13	0	0	.05	.043	.15	.162	.11	.105	0	.03	.06	.05	0	.028	.142	.042	"
" 14	.12	.12	.08	.08	.06	.10	0	0	.008	.006	.031	.033	.038	.036	0	.02	.03	.05	0	.008	.020	.021	"
" 18	.78	.12	.10	.10	.10	.65	.031	.015	.018	.014	.06	.065	.054	.051	.04	.10	.24	.38	.003	.021	.150	.142	"
" 19	.03	.03	.03	.03	.02	.13	.031	.015	.018	.014	.018	.019	.038	.036	.02	.04	.10	.16	.001	.008	.046	.064	"
" 20						.25	.024	.011	.024	.019	.038	.041	.038	.036	.02	.04	.05	.17	.001	.013	.082	.064	"
" 21	.24	.20	.18	.18	.16	.18	.12	.057	.16	.126	.018	.019	.18	.172	.03	.06	.03	.13	.009	.102	.012	.050	"
" 22	.72	.42	.28	.21	.18	.79	.16	.076	.23	.181	.58	.625	.43	.410	.24	.33	.84	.57	.088	.476	2.990	1.122	"
" 23						0	.06	.028	.18	.142	.41	.534	.26	.248	.01	.03	.10	.21	.004	.064	.535	.471	"
" 24						0	0	0	0	0	0	0	.004	.004	0	0	0	.10	0	0	0	.022	"
" 25- 31						.60[1]	0	0	0	0	0	0	.001	.001	0	0	0	.14	0	0	0	.014	"
Total October 29 to December 31															.72	1.24	3.78	4.23	.275	1.203	9.026	4.599	"
Total for Year 1933															4.97	1.85	3.93	5.94	.334	1.230	9.044	5.110	

Terrace No.	Drainage Area	Land Slope	Vertical Spacing	Length	Grade
	Acres	per cent	feet	feet	inches per 100 feet
7	2.09	14.5	15.0	780	12
5	1.26	20.0	15.0	780	12
17	.92	23.5	14.2	780	12
3A	1.04	27.6	15.0	780	12

1. Snow
2. Value is high—includes some water from Terrace 6 above
3. Squirrel hole 500 feet from outlet plugged at 9:30 A.M. Results adjusted accordingly.

TABLE NO. 13. EROSION AND RUNOFF FROM TERRACES WITH DIFFERENT GRADES

Date	Maximum Rates of Rainfall 5 Min.	10 Min.	15 Min.	20 Min.	30 Min.	Total Rain-fall	Maximum Rates of Run-off Terrace No. 13		Terrace No. 18		Terrace No. 17		Terrace No. 16		Terrace No. 15		Total Run-off Ter. 13	Ter. 18	Ter. 17	Ter. 16	Ter. 15	Soil Loss Per Acre Ter. 13	Ter. 18	Ter. 17	Ter. 16	Ter. 15	Remarks
1933	inches per hr	inches per hr	inches per hr	inches per hr	inches per hr	inches	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	inches	inches	inches	inches	inches	tons	tons	tons	tons	tons	
January 4						.10[1]	.004	.003	.001	.001	.004	.004	.038	.046	.07	.075	.02	.01	.02	.34	.64	0	0	.001	.013	.014	Ground cover
" 5						.07	.06	.039	.004	.003	.008	.009	.031	.037	.08	.089	.14	.01	.02	.34	.52	.002	.001	.001	.013	.010	of winter
" 6						0	0	0	0	0	0	0	0	0	.018	.020	0	0	0	0	.06	0	0	0	0	.016	wheat stubble
" 7	.12	.12	.12	.12	.12	.55	.001	.001	.004	.003	.001	.001	.018	.022	.018	.020	.02	.02	.05	.22	.21	0	.001	.003	.015	.027	"
" 8	.16	.16	.16	.12	.08	.26	.001	.001	.001	.001	0	0	.018	.022	.018	.020	.01	.01	0	.18	.25	0	0	0	.014	.033	"
" 9						.08	0	0	0	0	0	0	.004	.005	.008	.009	0	0	0	.04	.08	0	0	0	.003	.010	"
February 21						0	0	0	0	0	0	0	.004	.005	0	0	0	0	0	.05	0	0	0	0	.006	0	"
" 22	.12	.09	.08	.07	.07	.22	-	-	0	0	.004	.004	.013	.016	.038	.042	.02	.01	.03	.17	.23	.001	0	.003	.021	.027	"
" 25						.66[1]	.09	.008	0	0	0	0	0	0	.008	.009	.03	0	0	0	.02	.001	0	0	0	.003	"
" 27-28						.12	0	0	0	0	0	0	0	0	.031	.035	0	0	0	0	.12	0	0	0	0	.013	"
March 1						0	.024	.016	.001	.001	.004	.004	.018	.022	.018	.020	.06	.01	.02	.18	.14	.005	.002	.007	.044	.017	"
" 2	.24	.20	.20	.18	.16	.30	.11	.072	0	0	.001	.001	.024	.029	.038	.042	.46	0	.01	.15	.16	.051	0	.003	.038	.020	"
" 3						0	.054	.035	0	0	0	0	.008	.010	.008	.009	.17	0	0	.07	.09	.015	0	0	.017	.013	"
" 7-10						.57[1]	0	0	0	0	0	0	.008	.010	0	0	0	0	0	.03	0	0	0	0	.012	0	"
Total January 1 to March 10																	.93	.07	.15	1.77	2.52	.079	.004	.018	.196	.197	"
March 11 to October 28																	No Run-off										
October 29						0	-	-	0	0	0	0	-	-	-	-	.01	0	0	.02	.01	.001	0	0	.010	.004	Winter wheat
" 31	.36	.24	.22	.21	.16	.73	0	0	-	-	-	-	.013	.016	.008	.009	0	.01	.01	.07	.03	0	.005	.014	.036	.014	on summer
November 2	.30	.24	.22	.20	.18	.91	0	0	.031	.026	.06	.065	.054	.065	.06	.067	0	.05	.16	.23	.17	0	.044	.218	.058	.041	fallow
" 3	.48	.36	.28	.27	.22	.50	.20	.130	.12	.101	.15	.162	.15	.181	.19	.212	.14	.08	.28	.28	1.0	.010	.070	.378	.144	.786	"
" 4-5						0	0	0	0	0	0	0	.004	.005	0	0	0	0	0	.07	0	0	0	0	.014	0	"
December 6	.48	.36	.32	.21	.18	1.82	.19	.184	.31	.261	.48	.517	.39	.472	.54	.602	.34	.68[2]	.65[2]	.73	.91	.352	1.080	2.235	2.635	3.688	"
" 7-8						.20	0	0	.024	.020	.013	.014	.008	.010	.004	.004	0	.04	.06	.04	.01	0	.024	.240	.052	.016	"
" 9	.21	.18	.18	.18	.18	1.53	.19	.124	.16	.134	.09	.097	.06	.075	.08	.089	.80[3]	.97	.85	.74	1.00	.220[3]	.608	1.550	2.505	2.795	"
" 10	.12	.09	.08	.08	.08	.31	.07	.046	.07	.059	.08	.086	.054	.065	.008	.009	.14[3]	.11	.20	.20	.15	.038[3]	.069	.366	.471	.420	"
" 11	.20	.12	.12	.12	.10	.16	.018	.012	.024	.020	.031	.033	.024	.029	.013	.014	.03[3]	.03	.08	.08	.08	.003[3]	.016	.062	.058	.079	"
" 12						.17	.013	.008	0	0	.046	.050	.024	.029	.008	.009	.04[3]	0	.06	.10	.11	.004[3]	0	.046	.078	.109	"
" 13						.13	.018	.012	.10	.084	.15	.162	.14	.169	.19	.212	.06[3]	.03	.06	.15	.10	.006[3]	.035	.142	.355	.310	"
" 14	.12	.12	.08	.08	.06	.10	.013	.008	.024	.020	.031	.033	.038	.046	.001	.001	.03[3]	.02	.03	.11	.05	.003[3]	.008	.020	.072	.047	"
" 15-16						.50[1]	0	0	0	0	0	0	.001	.001	0	0	0	0	0	.04	0	0	0	0	.004	0	"
" 17						.15[1]	.013	.008	.001	.001	0	0	.004	.005	-	-	.02[3]	.01	0	.05	.13	.002[3]	.002	0	.004	.042	"
" 18	.18	.12	.10	.10	.10	.65	.110	.072	.06	.050	.06	.065	.038	.046	.059	.060	.38[3]	.25	.24	.29	.61	.050[3]	.092	.150	.224	.268	"
" 19	.03	.03	.03	.03	.02	.13	.070	.046	.046	.039	.018	.019	.031	.037	.046	.051	.17[3]	.09	.10	.17	.26	.026[3]	.038	.046	.151	.121	"
" 20						.45	.160	.104	.054	.045	.038	.041	.024	.029	.008	.009	.35[3]	.07	.05	.20	.16	.138[3]	.090	.022	.161	.073	"
" 21	.24	.20	.18	.18	.16	.18	.230	.150	.23	.193	.018	.019	.14	.169	.23	.252	.12[3]	.14	.03	.20	.24	.040[3]	.129	.012	.181	.111	"
" 22	.72	.42	.28	.21	.14	.79	.190	.124	.31	.261	.58	.625	.50	.605	.75	.813	.52[3]	.57	.84	.64	.81	.252[3]	.225	2.990	2.990	3.430	"
" 23						0	.150	.098	.23	.193	.41	.334	.22	.266	.34	.379	.09[3]	.05	.10	.16	.17	.052[3]	.109	.535	.699	1.075	"
" 24						0	0	0	0	0	0	0	.004	.005	.004	.004	0	0	0	.12	.10	0	0	0	.009	.006	"
" 25						0	0	0	0	0	0	0	.004	.005	.001	.001	0	0	0	.05	.02	0	0	0	.004	.001	"
" 26-27						.46[1]	0	0	0	0	0	0	.001	.001	.001	.001	0	0	0	.05	.04	0	0	0	0	.002	"
" 28						.07	.008	.005	.008	.007	0	0	.008	.010	.008	.009	0	0	0	.01	.07	0	0	0	0	.005	"
" 29						0	.013	.008	.008	.007	0	0	.008	.010	.004	.004	.01	.03	0	.05	.10	.001	.002	0	.004	.008	"
" 30						.07	0	0	.001	.001	0	0	.001	.001	.004	.004	.04	.03	0	.08	.10	.002	.002	0	.004	.008	"
" 31						0	0	0	0	0	0	0	0	0	.004	.004	0	.01	0	.02	.10	0	0	0	.001	.008	"
Total October 29 to December 31																	3.43	5.27	3.78	4.90	5.91	1.210	5.648	9.026	11.224	13.467	"
Total for Year 1933																	4.36	5.34	3.93	6.67	8.43	1.289	5.652	9.044	11.420	13.664	

Terrace No.	Drainage Area	Land Slope	Vertical Spacing	Length	Grade
	Acres	per cent	feet	feet	inches per 100 feet
13	1.52	15.2	13.8	780	0 (level)
18	1.18	18.4	14.0	780	6
17	.92	23.5	14.2	780	12
16	.82	26.7	13.5	780	18
15	.89	24.0	17.0	685	24

1. Snow
2. Squirrel hole 500 feet from outlet of terrace 17 was plugged at 9:30 A.M. and results are adjusted accordingly.
3. Run-off and soil loss is for combined areas of terraces 12 and 13.

TABLE NO. 14. EROSION AND RUN-OFF FOR WATER SHEDS OF DIFFERENT SIZES AND DIFFERENT VEGETATIVE COVER

Date	Maximum Rates of Rainfall 5 Min.	10 Min.	15 Min.	20 Min.	30 Min.	Total Rainfall	Maximum Rates of Runoff W.S. No. 4 sec. feet	W.S. No. 4 inches per hr	W.S. No. 5 sec. feet	W.S. No. 5 inches per hr	W.S. No. 6 sec. feet	W.S. No. 6 inches per hr	W.S. No. 2 sec. feet	W.S. No. 2 inches per hr	W.S. No. 7 sec. feet	W.S. No. 7 inches per hr	Total Run-off W.S. 4	W.S. 5	W.S. 6	W.S. 2	W.S. 7	Soil Loss Per Acre W.S. 4	W.S. 5	W.S. 6	W.S. 2	W.S. 7
1933	inches per hr	inches per hr	inches per hr	inches per hr	inches per hr	inches	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	sec. feet	inches per hr	inches	inches	inches	inches	inches	tons	tons	tons	tons	tons
January 1-3						1.61	0	0	0	0	0	0	0	0	7	.0004	0	0	0	0	.03	0	0	0	0	0
" 4						.10	.07	.030	.53	.037	.32	.021	2.57	.037	13	.0008	.21	.18	.09	.05	.01	.003	.017	.004	.008	0
" 5						.07	.32	.136	1.50	.103	.80	.052	12.01	.175	158	.0094	.80	.67	.51	1.64	.11	.011	.063	.020	.280	.004
" 6						0	.03	.013	.13	.009	.25	.016	.53	.008	158	.0094	.11	.12	.07	.05	.14	.002	.005	.001	.008	.003
" 7	.12	.12	.12	.12	.12	.55	.23	.098	1.30	.090	1.62	.102	6.68	.097	660	.0392	.84	.74	.75	.80	.30	.044	1.528	.035	.670	.043
" 8	.16	.16	.16	.12	.08	.26	.08	.034	.57	.039	.92	.060	2.82	.041	660	.0392	.37	.41	.67	.48	.54	.021	1.428	.011	.295	.122
" 9						.03	.03	.013	.66	.046	.46	.030	.88	.013	330	.0196	.13	.18	.30	.17	.29	.008	.565	.011	.073	.060
" 10						0	.03	.013	.06	.004	.04	.003	.13	.002	170	.0101	.07	.04	.05	.03	.14	.005	.069	.001	.002	.006
" 11-13						0	0	0	.20	.014	.03	.002	.20	.003	54	.0032	0	.22	.05	.08	.14	0	.745	-	.007	.005
" 14						.10	.01	.004	.16	.011	0	0	1.57	.025	103	.0061	.02	.18	0	.08	.08	.004	.747	0	.136	.046
" 15-31						1.59	0	0	0	0	0	0	.06	.001	41	.0036	0	0	0	.04	.43	0	0	0	.001	.014
February 1-20						1.55	0	0	0	0	0	0	0	0	6	.0003	0	0	0	0	.08	0	0	0	0	.002
" 21						0	.04	.017	0	0	0	0	.43	.006	80	.0048	.29	0	0	.05	.02	.006	0	0	.013	.001
" 22	.12	.09	.08	.07	.07	.22	.12	.051	.20	.014	.58	.038	5.77	.084	330	.0196	.50	.12	.34	.62	.26	.010	.015	.040	.174	.051
" 23						.66	.04	.017	.02	.001	.51	.033	.62	.009	175	.0116	.06	.01	.07	.04	.17	.001	-	.001	.001	.006
" 24						.03	0	0	.01	.001	0	0	.02	.003	135	.0080	0	.01	0	.03	.14	0	-	0	.001	.005
" 25						0	.07	.030	.01	.001	0	0	.02	.0003	68	.0040	.17	.01	0	0	.08	.013	-	0	0	.002
" 26						.22	.04	.017	0	0	0	0	.08	.0003	42	.0025	.08	0	0	0	.05	.006	0	0	0	.001
" 27						0	0	0	0	0	0	0	.04	.001	32	.0019	0	0	0	0	.04	0	0	0	0	.001
" 28						.12	.06	.026	0	0	0	0	.27	.004	21	.0012	.02	0	0	0	.02	.007	0	0	0	.001
March 1						0	.18	.077	.31	.021	.18	.012	2.09	.030	126	.0075	.54	.18	.13	.30	.10	.054	.059	.003	.039	.017
" 2	.24	.20	.20	.18	.16	.30	.20	.085	.53	.037	.58	.038	2.32	.034	296	.0175	.58	.25	.31	.34	.20	.058	.121	.026	.212	.098
" 3						0	.08	.034	.20	.014	.49	.032	1.72	.025	276	.0164	.22	.06	.17	.26	.29	.022	.032	.003	.168	.068
" 4-6						.01	0	0	.04	.003	.18	.012	.58	.008	131	.0078	0	.09	.17	.19	.35	0	.012	.003	.005	.018
" 7						.25	.04	.017	.01	.001	.28	.018	.92	.014	185	.0110	.08	.01	.15	.12	.21	.006	.006	.003	.203	.064
" 8						0	.06	.026	.01	.001	.10	.006	.71	.010	171	.0101	.09	.01	.05	.06	.15	.006	.018	.001	.034	.087
" 9						.34	0	0	0	0	.04	.003	.13	.002	85	.0050	0	0	.05	.03	.09	0	0	.006	.003	.084
" 10						0	.06	.026	.34	.23	.03	.002	.66	.010	100	.0059	.09	.19	.04	.06	.08	.006	1.082	.005	.006	.060
" 11						0	.01	.004	.20	.014	.71	.046	2.90	.042	392	.0233	.03	.13	.32	.28	.25	.002	.729	.043	.690	.184
" 12						.03	0	0	.23	.016	1.23	.080	2.73	.0397	785	.0466	0	.16	.53	.30	.49	0	.601	.069	.551	.650
" 13						0	0	0	.08	.006	.43	.028	.71	.0103	342	.0203	0	.10	.22	.07	.30	0	.121	.011	.140	.237
" 14						0	0	0	.08	.006	.58	.038	.71	.0103	478	.0284	0	.07	.24	.09	.30	0	.159	.022	.285	.382
" 15						0	0	0	.11	.008	.35	.023	.27	.0039	380	.0226	0	.09	.18	.08	.28	0	.347	.026	.096	.251
" 16						.07	0	0	.11	.008	.25	.016	.23	.0033	296	.0176	0	.11	.16	.06	.24	0	.175	.011	.037	.197
" 17						0	0	0	.04	.003	.06	.004	.27	.0039	208	.0124	0	.05	.07	.05	.18	0	.081	.005	.010	.106
" 18						.05	0	0	.04	.003	.06	.004	.13	.0019	141	.0084	0	.03	.06	.05	.14	0	.081	.006	.011	.088
" 19						0	0	0	.04	.003	.06	.004	.16	.0023	198	.0118	0	.04	.08	.03	.17	0	.108	.008	.005	.036
" 20						.02	0	0	.06	.004	.06	.004	.16	.0023	192	.0114	0	.04	.08	.03	.20	0	.108	.005	.002	.124
" 21						.10	0	0	.01	.001	.06	.004	.25	.0033	118	.0070	0	.01	.06	.02	.11	0	.003	.001	.002	.012
" 22						.04	0	0	.01	.001	.04	.003	.13	.0019	90	.0054	0	.01	.06	.03	.08	0	.003	.001	.004	.023
" 23						0	0	0	.01	.001	.04	.003	.08	.0012	75	.0043	0	.01	.06	.02	.07	0	.003	.001	.002	.015
" 24						0	0	0	.01	.001	.04	.003	.11	.0016	60	.0036	0	.01	.06	.02	.06	0	.003	.001	.003	.012
" 25						.04	0	0	.01	.001	.04	.003	.08	.0012	78	.0046	0	.02	.06	.02	.07	0	.006	.001	.001	.004
" 26						0	0	0	.01	.001	.04	.003	.08	.0012	66	.0040	0	.02	.06	.02	.07	0	.006	.001	.001	.006
" 27						0	0	0	.01	.001	.04	.003	.08	.0012	56	.0034	0	.02	.06	.02	.07	0	.006	.001	-	.006
" 28						.21	0	0	.01	.001	.04	.003	.08	.0012	115	.0068	0	.02	.06	.03	.12	0	.006	.001	.003	.022
" 29						.15	0	0	.01	.001	.04	.003	.08	.0012	85	.0050	0	.02	.06	.02	.09	0	.006	.001	.001	.022
" 30						.30	0	0	.01	.001	.04	.003	.35	.0135	108	.0064	0	.02	.06	.04	.08	0	.006	.001	.001	.008
" 31						0	0	0	.01	.001	.06	.004	.08	.0012	92	.0055	0	.01	.09	.02	.07	0	.003	.002	.001	.012
April 1-12						.12	0	0	0	0	.04	.003	.08	.001	34	.0020	0	.01	.04	.03	.23	0	.003	.005	.002	.007
" 13-21						.12	0	0	0	0	0	0	0	0	10	.0006	0	0	0	0	.07	0	0	0	0	.005
" 22-30						.29	0	0	0	0	0	0	0	0	4	.0002	0	0	0	0	.05	0	0	0	0	.001
May 1-31						.89	0	0	0	0	0	0	0	0	4	.0002	0	0	0	0	.12	0	0	0	0	0
June 1-July 11						1.32	0	0	0	0	0	0	0	0	4	.0002	0	0	0	0	.03	0	0	0	0	0
Total January 1 to July 11																	5.30	4.70	6.84	6.05	8.10	.895	9.058	.397	4.195	3.857
July 12 to September 8																	No Run-off									
September 9						.21	0	0	0	0	0	0	0	0	920	.0546	0	0	0	0	.11	0	0	0	0	.028
" 10						0	0	0	0	0	0	0	0	0	24	.0014	0	0	0	0	.01	0	0	0	0	.005
" 11-30						1.40	0	0	0	0	0	0	0	0	3	.0002	0	0	0	0	.01	0	0	0	0	0
October 1-27						2.11	0	0	0	0	0	0	0	0	9	.0005	0	0	0	0	.02	0	0	0	0	.001
" 28-31	.36	.24	.22	.21	.16	2.30	-	-	0	0	.92	.060	0	0	79	.0047	.07	0	.06	0	.06	.070	0	.003	0	.014
November 1-2	.30	.24	.22	.20	.18	1.02	.28	.119	0	0	1.23	.080	.15	.002	21	.0012	.17	0	.17	0	.22	.066	0	.007	.0	.004
" 3	.48	.36	.28	.27	.22	.50	.51	.217	0	0	4.50	.294	1.24	.018	208	.0124	.21	0	.43	.05	.11	0	0	.161	.011	.171
" 4-30						.21	0	0	0	0	.02	.001	0	0	10	.0006	0	0	.04	0	.12	0	0	-	0	.025
December 1-5						.76	.03	.013	0	0	.23	.015	.06	.001	8	.0005	.05	0	.08	0	.02	.006	0	.066	0	.004
" 6	.48	.36	.32	.21	.18	1.82	.59	[illegible]	.04	.003	5.96	.389	5.34	.077	464	.0280	1.23	.05	.87	.29	.32	4.900	.005	5.310	1.662	.018
" 7						0	.01	.004	.02	.001	.04	.003	.20	.005	143	.0085	.01	.02	.02	.02	.04	.007	-	-	.003	.010
" 8						.20	.03	.013	.02	.001	.12	.008	.13	.002	19	.0012	.03	.01	.02	.01	.01	.022	.001	-	.002	.001
" 9	.21	.18	.18	.18	.18	1.53	.32	.149	.02	.001	1.70	.108	3.44	.050	1062	.0631	1.01	.03	.78	.49	.67	1.418	.001	1.706	.485	.880
" 10	.18	.09	.08	.08	.08	.31	.16	.068	.02	.001	1.44	.094	2.40	.035	256	.0152	.22	.05	.18	.15	.18	.359	-	.011	.008	.190
" 11	.20	.12	.12	.12	.10	.16	.06	.026	.01	.001	.28	.018	.45	.006	135	.0080	.15	.01	.08	.05	.06	.019	0	.005	-	.005
" 12						.17	.04	.017	.02	.001	.20	.013	.66	.010	135	.0080	.02	.03	.07	.05	.11	.012	.001	.004	.005	.049
" 13-14	.12	.12	.08	.08	.06	.23	.40	.170	.02	.001	1.23	.080	1.57	.023	60	.0036	.14	.04	.13	.08	.09	.182	.001	.004	.021	.044
" 15-16						.50	0	0	.02	.001	.10	.006	.31	.004	21	.0012	0	.06	.12	.07	.04	0	.001	.002	.021	.008
" 17						.15	.06	.026	.20	.014	.08	.005	1.50	.022	135	.0080	.05	.06	.10	.10	.03	.009	-	.020	.042	.002
" 18	.16	.12	.10	.10	.10	.65	.14	.060	.20	.014	.92	.060	2.16	.031	462	.0275	.35	.10	.36	.34	.24	.242	.006	.065	.206	.377
" 19	.03	.03	.03	.05	.02	.13	.08	.034	.15	.009	.74	.048	1.93	.028	303	.0180	.11	.09	.16	.19	.24	.051	.003	.004	.021	.088
" 20						.25	.12	.051	.02	.001	.74	.048	2.09	.030	375	.0223	.16	.03	.19	.21	.27	.132	.001	.015	.038	.132
" 21	.24	.20	.18	.18	.16	.18	.54	.230	.23	.016	3.52	.229	7.15	.104	356	.0211	.25	.08	.23	.25	.21	.380	.001	.070	.041	.076
" 22	.72	.42	.28	.21	.18	.79	1.11	.472	.39	.027	4.12	.269	8.12	.118	990	.0588	.72	.17	.45	.49	.68	1.015	.002	.457	.770	1.289
" 23						0	.64	.272	.20	.014	4.31	.281	6.00	.087	296	.0176	.19	.10	.15	.14	.28	.420	.001	.006	.016	.128
" 24						0	.01	.004	.04	.005	.04	.003	.31	.004	50	.0030	.10	0	.06	.11	.05	.010	0	.001	.012	.005
" 25						0	.0001	.002	0	0	.04	.003	.31	.004	42	.0025	.05	0	.06	.09	.05	.005	0	.001	.006	.002
" 26						.45	.0004	.002	0	0	.04	.003	.43	.006	42	.0025	.05	0	.06	.10	.05	.005	0	.001	.005	.002
" 27						0	.0002	.002	0	0	.04	.003	.24	.003	37	.0022	.05	0	.06	.08	.05	.005	0	.001	.001	.002
" 28						.07	.001	.004	0	0	.04	.003	.48	.007	116	.0069	.07	0	.06	.10	.08	.007	0	.001	.008	.005
" 29						0	.03	.013	.04	.003	.04	.003	.77	.011	135	.0085	.10	.07	.06	.13	.11	.010	.005	.001	.005	.011
" 30-31						.07	.04	.017	.02	.001	.04	.003	.27	.004	77	.0046	.01	.06	.12	.16	.12	.001	.001	.001	.002	.006
Total September 9 to December 31																	5.43	1.15	5.19	3.71	4.58	10.966	.028	7.919	3.535	4.986
Total Year 1933																	10.73	5.85	12.03	10.54	13.06	11.261	9.084	8.316	7.730	8.843